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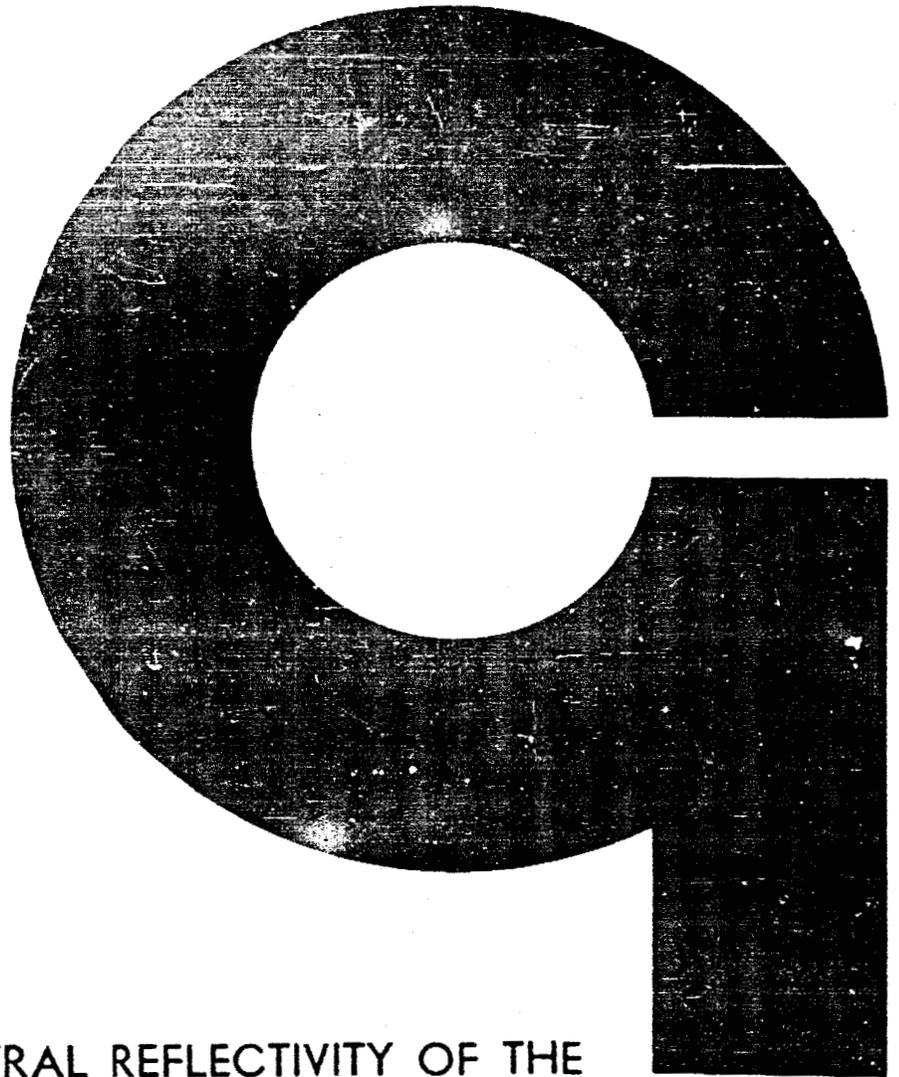
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[SPECTRAL REFLECTIVITY OF THE
EARTH'S ATMOSPHERE II:]
A CONGERIES OF ABSORPTION CROSS
SECTIONS FOR WAVELENGTHS LESS THAN 3000 Å

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SPECTRAL REFLECTIVITY OF THE EARTH'S ATMOSPHERE II:
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TABLE OF CONTENTS

<u>Section</u>	<u>Title</u>	<u>Page</u>
I	INTRODUCTION	1
II	ABSORPTION CROSS SECTION STUDIES	4
A.	<u>Oxygen</u>	4
	1. Historical Survey	4
	2. Spectral Region 1850 Å to 2500 Å. The Herzberg Continuum	5
	3. Spectral Region 1250 Å to 2000 Å. The Schumann-Runge Continuum and Bands	6
	4. Spectral Region 1100 Å to 1250 Å	7
	5. Spectral Region 850 Å to 1100 Å	7
	6. Spectral Region 100 Å to 850 Å. The Extreme Ultraviolet	8
B.	<u>Ozone</u>	8
	1. Historical Survey	8
	2. Spectral Region 2000 Å to 3000 Å	9
	3. Spectral Region 1000 Å to 2000 Å	9
	4. Spectral Region 520 Å to 1000 Å	10
C.	<u>Carbon Dioxide</u>	10
	1. Historical Survey	10
	2. Spectral Region 1000 Å to 1800 Å	11
	3. Spectral Region Below 1000 Å	11
D.	<u>Carbon Monoxide</u>	12
	1. Historical Survey	12
	2. Spectral Region 1000 Å to 1600 Å	12
	3. Spectral Region Below 1000 Å	13
E.	<u>Water Vapor</u>	13
	1. Historical Survey	13
	2. Ultraviolet Spectral Region	14
F.	<u>Nitrogen</u>	15
	1. Historical Survey	15
	2. Spectral Region 800 Å to 1450 Å	15
	3. Spectral Region Below 800 Å	16
G.	<u>Argon</u>	16

TABLE OF CONTENTS (continued)

<u>Section</u>	<u>Title</u>	<u>Page</u>
H	<u>Nitric Oxide</u>	17
	1. Historical Survey	17
	2. Spectral Region 1000 Å to 2300 Å	17
	3. Spectral Region Below 1000 Å	18
I.	<u>Nitrous Oxide</u>	18
	1. Historical Survey	18
	2. Spectral Region 1000 Å to 2200 Å	19
	3. Spectral Region Below 1000 Å	19
J.	<u>Nitrogen Dioxide</u>	20
	1. Historical Survey	20
	2. Ultraviolet Spectral Region	20
K.	<u>Ammonia</u>	21
	1. Historical Survey	21
	2. Ultraviolet Spectral Region	21
L.	<u>Methane</u>	22
	1. Historical Survey	22
	2. Ultraviolet Spectral Region	22
TABLES		23
FIGURES		61
DIRECT REFERENCES		92
INDIRECT REFERENCES		94

LIST OF TABLES

Absorption Coefficients

	<u>Page</u>
1. Summary of Absorption Cross Section Studies by Investigators.	23
2. Oxygen: 100 to 370 Å (Aboud <u>et al.</u>)	24
3. Oxygen: 300 to 1300 Å (Weissler <u>et al.</u>)	25
4. Oxygen: 840 to 1900 Å (Watanabe <u>et al.</u>)	26
5. Ozone: 525 to 1300 Å (Ogawa and Cook)	34
6. Ozone: 2000 to 3000 Å (Inn and Tanaka).	35
7. Carbon Dioxide: 150 to 750 Å (Romand)	36
8. Carbon Dioxide: 375 to 1300 Å (Weissler <u>et al.</u>)	37
9. Carbon Dioxide: 1050 to 1750 Å (Watanabe <u>et al.</u>)	38
10. Carbon Monoxide: 375 to 1300 Å (Weissler <u>et al.</u>)	42
11. Water Vapor: 150 to 1100 Å (Romand)	43
12. Water Vapor: 850 to 1850 Å (Watanabe <u>et al.</u>)	44
13. Nitrogen: 150 to 950 Å (Romand)	48
14. Nitrogen: 300 to 1300 Å (Weissler <u>et al.</u>)	49
15. Nitrogen: 850 to 1000 Å (Watanabe <u>et al.</u>)	50
16. Argon: 600 to 850 Å (Weissler <u>et al.</u>)	51
17. Nitric Oxide: 150 to 1000 Å (Romand).	52
18. Nitric Oxide: 375 to 1300 Å (Weissler <u>et al.</u>)	53
19. Nitric Oxide: 1065 to 1350 Å (Watanabe <u>et al.</u>)	54
20. Nitrous Oxide: 150 to 1000 Å (Romand)	55
21. Nitrous Oxide: 1080 to 2160 Å (Watanabe <u>et al.</u>)	56
22. Ammonia: 375 to 1300 Å (Weissler <u>et al.</u>)	59
23. Methane: 375 to 1300 Å (Weissler <u>et al.</u>)	60

LIST OF FIGURES

Absorption Coefficients and Cross Sections

	<u>Page</u>
1. Summary of Absorption Cross Section Studies by Region. . .	61
2. Oxygen: 100 to 650 Å (Aboud <u>et al.</u>)	62
3. Oxygen: 300 to 1300 Å (Weissler <u>et al.</u>)	63
4. Oxygen: 340 to 1900 Å (Watanabe <u>et al.</u>)	64
5. Oxygen: 1850 to 2500 Å (Ditchburn and Young).	65
6. Ozone: 525 to 1300 Å (Ogawa and Cook)	66
7. Ozone: 1050 to 2200 Å (Watanabe <u>et al.</u>)	67
8. Ozone: 2000 to 3000 Å (Inn and Tanaka).	68
9. Carbon Dioxide: 150 to 750 Å (Romand)	69
10. Carbon Dioxide: 350 to 1300 Å (Weissler <u>et al.</u>)	70
11. Carbon Dioxide: 1050 to 1750 Å (Watanabe <u>et al.</u>)	71
12. Carbon Monoxide: 350 to 1300 Å (Weissler <u>et al.</u>)	72
13. Carbon Monoxide: 1050 to 1650 Å (Watanabe <u>et al.</u>)	73
14. Water Vapor: 150 to 1100 Å (Romand)	74
15. Water Vapor: 850 to 1850 Å (Watanabe <u>et al.</u>)	75
16. Nitrogen: 150 to 950 Å (Romand)	76
17. Nitrogen: 300 to 1200 Å (Weissler <u>et al.</u>)	77
18. Nitrogen: 850 to 1000 Å (Watanabe <u>et al.</u>)	78
19. Argon: 350 to 825 Å (Weissler <u>et al.</u>)	79
20. Nitric Oxide: 150 to 1000 Å (Romand).	80
21. Nitric Oxide: 375 to 1300 Å (Weissler <u>et al.</u>)	81
22. Nitric Oxide: 1065 to 2300 Å (Watanabe <u>et al.</u>)	82
23. Nitrous Oxide: 150 to 1000 Å (Romand)	83
24. Nitrous Oxide: 675 to 950 Å (Weissler <u>et al.</u>)	84
25. Nitrous Oxide: 1080 to 2160 Å (Watanabe <u>et al.</u>)	85
26. Nitrogen Dioxide: 1080 to 1975 Å (Watanabe <u>et al.</u>)	86
27. Nitrogen Dioxide: 1920 to 2700 Å (Watanabe <u>et al.</u>)	87
28. Ammonia: 375 to 1300 Å (Weissler <u>et al.</u>)	88
29. Ammonia: 1060 to 2200 Å (Watanabe <u>et al.</u>)	89
30. Methane: 375 to 1300 Å (Weissler <u>et al.</u>)	90
31. Methane: 1065 to 1610 Å (Watanabe <u>et al.</u>)	91

A CONGERIES OF ABSORPTION CROSS SECTIONS
FOR WAVELENGTHS LESS THAN 3000 Å

A. C. Holland . E. D. Schultz
and F. F. Marmo

I. INTRODUCTION

The absorption of solar vacuum ultraviolet radiation by atmospheric gases is of primary importance in any comprehensive study of planetary aeronomy. Absorption cross section measurements have been made by numerous investigators, but their results are scattered throughout the literature. Some general surveys of these studies do exist (see, for example, References 3, 19, and 27); however, a detailed and up-to-date collection of absorption cross sections in the vacuum ultraviolet will serve as a ready aid for investigating atmospheric problems.

The purpose of this report is to begin such a compilation of experimental data. To obtain this presentation, the literature was searched for current experimental data and reviews of investigations in this area. In a few cases, data were obtained through private communication with particular investigators. Available absorption curves and tabulations, in the spectral region from 100 Å to 3000 Å, of various authors were collected and identified. In each case where tabulated values of absorption coefficients or cross sections were available, plots in this report were constructed by connecting points with straight line segments. Where curves but not tabulations were available, the curves were reproduced either directly or by linearizing semi-log figures. Table 1 is a block summary of authors whose studies are included in this compilation. In

Tables 2 through 23 appear the pure experimental data. Figure 1 is a graphical summary of the respective spectral regions studied--all which appear in Figures 2 through 31 and which were reproduced without attempted interpretation.

Two lists of references follow the discussion. The Direct List includes those authors whose articles have been consulted for this study and/or whose data have been plotted in the absorption cross section figures. The Indirect List includes authors whose works have been cited herein but were not directly consulted.

Included among the gases which are known or suspected to be present in the Earth and/or other planetary atmospheres are:

Oxygen	Argon
Ozone	Nitric Oxide
Carbon Dioxide	Nitrous Oxide
Carbon Monoxide	Nitrogen Dioxide
Water Vapor	Ammonia
Nitrogen	Methane

An accompanying brief discussion of the absorption characteristics together with a historical sketch of each gas considered appear below. Where extracts were published in a format similar to the intended pattern of this report, the authors are quoted directly. In this respect, it is emphasized that our purpose is to accumulate existing information in this area and to present a fairly complete package for convenient reference and availability in the present systematic study of planetary aeronomy

and for future applications. The contents will be updated and/or extended as more refined data are made available.

II. ABSORPTION CROSS SECTION STUDIES

A. OXYGEN

1. Historical Survey^(3,8,27)

Ditchburn and Young (1962) measured absorption cross sections for the Herzberg dissociation continuum in the spectral region from 2000 Å to 2500 Å and calculated values for the region from 1850 Å to 2000 Å. In the region of the Schumann-Runge continuum, absorption coefficients were first measured by Ladenburg and Van Voorhis (1933), and later measured by Schneider (1937). Absorption coefficients for this region were calculated by Stueckelberg (1932). Recently, the measurements were repeated by Watanabe et al. (1953a) and by Ditchburn and Heddle (1953). Below 1300 Å, the absorption spectrum was first observed by Price and Collins (1935) and by Tanaka (1952). The absorption of O₂ at the Lyman-alpha line has been measured by Preston (1940), and more recently by Watanabe et al. (1953a), Ditchburn et al. (1954), and Lee (1955). Weissler and Lee (1952) reported absorption coefficients below 1300 Å. Watanabe et al. (1953a) obtained the contour of O₂ in the region 1050 Å to 1350 Å, but the results were considered by the authors as semiquantitative. Watanabe et al. (1958) and Watanabe (1958, 1961) reinvestigated this area. Clark (1952) presented absorption values below 1000 Å. Lee (1955) measured the region from 200 Å to 1320 Å to establish the range and magnitude of the continua therein. Aboud et al. (1955) presented preliminary absorption results in the region down to 100 Å.

2. Spectral Region 1850 Å to 2500 Å. The Herzberg Continuum ⁽²⁾

Herzberg (1932) discovered a weak system of bands and an associated continuum in molecular oxygen in the spectral region 1850 Å to 2600 Å. He attributed the bands to the forbidden transition ${}^3\Sigma_g^- \rightarrow {}^3\Sigma_u^+$ and the continuum to the dissociation $O_2({}^3\Sigma_g^-) \rightarrow O({}^3P) + O({}^3P)$. The bands have been investigated experimentally by Chalonge and Vassy (1934), Herzberg (1952) and Broida and Gaydon (1954). Theoretical calculations have been made by Pillow (1953). Heilpern (1941) measured the absorption of oxygen at a single wavelength (2144 Å) in the continuum and Vassy (1941) measured absorption of air at wavelengths from 4000 Å to 1900 Å. Some measurements of oxygen have been reported in a thesis by Stopes-Roe (1947). The band spectrum has been observed in the spectrum of the night sky by Meinel (1951).

Ditchburn and Young's (1962) measured values include the effects due to Rayleigh scattering, which may amount to a maximum of $0.4 \times 10^{-24} \text{ cm}^2$ at 1900 Å. This is less than the experimental error of $\pm 1.0 \times 10^{-24} \text{ cm}^2$ quoted by the investigators. The data taken below 2000 Å was obscured by the overlying Schumann-Runge bands which are approximately 10^6 times stronger than the Herzberg continuum. To extend the continuum to smaller wavelengths, qualitative calculations of the absorption cross sections were made for different values of the internuclear distance; those for $r_e = 1.50 \text{ Å}$ agreed best with the measured values. The calculated values show a maximum value of absorption of

$15 \times 10^{-24} \text{ cm}^2$ at 1870 \AA and yield a total oscillator strength for the continuum of 3.5×10^{-5} .

3. Spectral Region 1250 \AA to 2000 \AA . The Schumann-Runge Continuum and Bands (19)

The bands (1750 \AA to 2000 \AA) which overlap the Herzberg continuum are attributed to the transition $^3\Sigma_g^- \rightarrow ^3\Sigma_u^-$ and the continuum to the dissociative transition $^3\Sigma_g^- \rightarrow ^3\Pi_u$. The bands have been studied by Curry and Herzberg (1934), Knauss and Ballard (1935), and more recently by Brix and Herzberg (1954) and Wilkinson and Mulliken (1957). These latter investigators concluded that the photochemical dissociation of O_2 in the region 1750 \AA to 1850 \AA consists of predissociation and direct dissociation involving the $^3\Pi_u$ state.

Watanabe et al. (1953b) obtained absorption cross section values for the bands with a resolution of 1 \AA . They indicate that their maxima are probably too low and their minima too high, but that their results are consistent with those of other investigators. The region from 1250 \AA to 1750 \AA shows essentially continuous absorption, but Watanabe et al. (1952) and Tanaka (1952) reported three diffuse bands or narrow continua between 1293 \AA and 1352 \AA . Tanaka suggests that the band at 1293 \AA leads to the dissociation product $^3\text{P} + ^1\text{S}$ and the other two bands to $^1\text{D} + ^1\text{D}$ or $^3\text{P} + ^1\text{S}$. Watanabe et al. (1953a) reported an f-value for the Schumann-Runge continuum of 0.161.

4. Spectral Region 1100 Å to 1250 Å (19)

Price and Collins (1935) and recently Tanaka (1952) attribute the diffuseness of the bands which occupy this region to pre-dissociation. Contained in this area are seven deep windows including one at Lyman- α (1215.7 Å) at which the absorption cross section reduces to $1.0 \times 10^{-20} \text{ cm}^2$. It is suggested that since solar Lyman- α reaches the D-layer through this window, its enhancement during chromospheric eruption may be responsible for radio fadeout. It is apparent that most of the bands are pressure dependent at comparatively low pressures. Underlying the bands, there probably exists a weak continuum with a maximum absorption cross section of about 10^{-20} cm^2 .

5. Spectral Region 850 Å to 1100 Å (7,10,19)

Hopfield (1930) first studied the bands, which bear his name, within this region. Many of the bands are expected to be members of the Rydberg series converging to the first ionization potential at 1026.5 Å. Price and Collins (1935) and Tanaka (1952) have investigated this. Matsunaga and Watanabe (1961), who measured this region with an improved resolution of 0.2 Å, observed a pressure effect for the pre-ionized H, H', M and M' bands. A weak dissociation continuum is apparent in the region from 1030 Å to 1100 Å, which Lee (1955) attributed to the dissociation transition $O_2(3\Sigma_g^-) \rightarrow O_2^+ X^2\Pi_3$. An ionization continuum is apparent beginning near 1030 Å. Also in the region from 850 Å to 1030 Å there is probably a weak dissociation continuum.

6. Spectral Region 100 Å to 850 Å.^(1,8) The Extreme Ultra-violet

This spectral region is characterized by strong continuous absorption upon which are superimposed band absorption corresponding to several series believed to be associated with the ionization of O_2 . Based on measured minima for the continuum, an f-value of 6.9 was computed by Aboud et al. (1955). However, they report that, due to scattered light, the data below 300 Å from their investigation⁽¹⁾ has little meaning. To the region from 683 Å to 740 Å, Lee (1955) attributed the molecular transition $O_2(3\Sigma_g^-) \rightarrow O_2^+(A^2\Pi_u)$ and to the region from 200 Å to 683 Å, he attributed $O_2(3\Sigma_g^-) \rightarrow O_2^+(b^4\Sigma_g^-)$. The Hopfield bands, which extend to 680 Å, form three Rydberg series that converge to the second, third and fourth ionization limits of O_2 at 770 Å, 730 Å and 680 Å. An additional Rydberg series converging to 610 Å was found by Tanaka and Takamine (1942).

B. OZONE

1. Historical Survey⁽³⁾

Hartley (1881) is usually credited with identifying atmospheric ozone as the cause of the abrupt cutoff of the ultraviolet solar spectrum at about 3000 Å. Ultraviolet absorption coefficients were first measured by Fabry and Buisson (1913). Fabry and Buisson (1921) confirmed the solar spectrum ultraviolet cutoff by ozone. Subsequent measurements in the ultraviolet and visible spectral regions were made by Ny and Choong (1933) and recently by Vigroux (1952), Inn and Tanaka (1953) and Hearn (1961),

and in the far ultraviolet by Tanaka et al. (1953) and Ogawa and Cook (1958).

2. Spectral Region 2000 Å to 3000 Å^(3,4)

Hartley (1881) discovered a strong system of bands and an associated continuum in ozone in the spectral range 2100 Å to 3200 Å. The system consists of a series of diffuse bands extending from 2340 Å to 3200 Å, followed by a strong absorption continuum to 2100 Å. The weaker Huggins bands, 3200 Å to 3400 Å, were discovered by Huggins (1890) in the spectrum of Sirius. Fowler and Strutt (1917) found the Huggins bands in the low-sun spectrum and also in the laboratory spectrum of ozone. The absorption coefficients in this region have been measured in detail by Ny and Choong (1933), whose data stood as the best available until the experiments conducted by Inn and Tanaka (1953) and Vigroux (1953). Hearn (1961) made measurements of the absorption coefficients at the wavelengths of six mercury lines in the region, the results of which agreed generally with those of Inn and Tanaka. These latter authors calculated an f-value for the continuum of 0.088.

3. Spectral Region 1000 Å to 2000 Å^(i,16)

Above 1300 Å, there appear to be continua with maxima at 1330 Å, 1450 Å, and 1725 Å. The continuum that peaks at 1725 Å merges at about 2000 Å with the strong Hartley continuum which has a maximum at 2550 Å. A number of bands appear in the region from 1060 Å to 1350 Å

but, due to the weakness of these bands and the presence of the continuum, a determination of the progressions is difficult. The bands are probably members of a Rydberg series. The peaks of the continua in the region occur at 1120 Å and 1215 Å. In the region of the Schumann-Runge continuum, ozone absorption is almost as strong as oxygen absorption.

4. Spectral Region 520 Å to 1000 Å⁽¹¹⁾

Preliminary absorption coefficient measurements of ozone were made in the region from 520 Å to 1350 Å by Ogawa and Cook (1958). The pressures were not directly determined, but only relative changes were measured. Thus, only relative absorption coefficients were directly determined. Absolute values were obtained by matching the coefficient at Lyman- α obtained by Ogawa and Cook with that obtained by Tanaka *et al.* (1953). In the region from 520 Å to 750 Å, some weak bands overlapping the continuum were found.

C. CARBON DIOXIDE

1. Historical Survey^(13c)

The structure and systematics of the resonance absorption bands of CO₂ in the vacuum ultraviolet have been studied by several investigators with, however, very few measurements reported for the absorption cross sections. The bands were studied by Lyman (1908), Leifson (1926), Henning (1932), Rathenau (1934), and Price and Simpson (1938). Wilkinson and Johnston (1950) measured absorption cross sections

between 1440 Å and 1670 Å, and separately, Inn et al. (1953) carried out a more extensive and detailed study in the same region down to 1060 Å. Preston (1940) obtained data at Lyman- α . Measurements in the region from 375 Å to 1300 Å were made by Sun and Weissler (1955c) and recently, Romand (1962) has provided data for the region from 150 Å to 750 Å.

2. Spectral Region 1000 Å to 1800 Å⁽⁷⁾

Inn et al. (1953) reported three and possibly four continua in this area. They calculated an f-value of 0.0043 for the continuum that peaks at 1475 Å. The more intense continuum (λ_{max} at 1332 Å) gave an f-value of 0.0053. The low f-values of these continua seem to indicate forbidden electronic transitions. The strong continuum (λ_{max} at 1121 Å) gave an f-value of 0.12, indicating an allowed electronic transition. Bands in this region have been shown by Price and Simpson (1938) to contain the second members of a Rydberg series, which converges to the first ionization potential at 903 Å, as determined by the authors.⁽⁷⁾

3. Spectral Region Below 1000 Å^(13c,27,30)

Strong resonance bands extend from 1300 Å to 700 Å, with one of them at 923 Å showing an usually large cross section ($117 \times 10^{-18} \text{ cm}^2$). A continuum with bands superimposed in it starts at about 860 Å, the value determined by Sun and Weissler (1955c) as the first ionization potential. Strongly preionized bands are in evidence between 750 Å and 850 Å. From 700 Å toward shorter wavelengths, the contour of the continuum is better defined

and smooth. Sun and Weissler (1955c) give an f -value of 4.4 for this continuum, which is probably due to photoionization of the molecule since no conspicuous bands due to dissociative ionization reactions were observed.^(13c) Indication of a small discontinuity in the absorption contour in the neighborhood of 700 \AA seems due to the appearance of O^+ . Furthermore, CO^+ appears at about 645 \AA .⁽³⁰⁾

D. CARBON MONOXIDE

1. Historical Survey^(13c)

Vacuum ultraviolet absorption bands of CO were investigated by Hopfield and Birge (1927), Henning (1932) and Tanaka and Takamine (1942, 1943). There appears to have been little work done on absorption coefficients. Watanabe et al. (1953b) obtained relative absorption intensity data between 1050 \AA and 1650 \AA , and Sun and Weissler (1955c) covered the region from 375 \AA to 1300 \AA .

2. Spectral Region 1000 \AA to 1600 \AA ⁽²⁵⁾

Carbon monoxide has a very rich absorption spectrum in the spectral region between 1100 \AA and 1600 \AA . There are many strong bands, particularly the well-known IVth positive bands, $X^1\Sigma \rightarrow A^1\Pi$. Because of their sharpness, however, very little quantitative data are available. A weak continuum between 1300 \AA and 1600 \AA , which resembles the Schumann-Runge continuum, is apparent in the results obtained by Watanabe et al. (1953b). It is possible that this continuum was due to the presence of

O_2 in the CO sample. The absorption coefficients measured by the authors were apparent ones and were obtained with insufficient absorption.⁽²⁵⁾ The wavelengths of many of the strong absorption bands in the region 1060 Å to 1170 Å agree with those of the $X \rightarrow C$ and $X \rightarrow E$ transitions found by Hopfield and Birge (1927). In this latter region a continuum was observed⁽²⁵⁾ to begin at about 1140 Å with moderately strong intensity at 1060 Å.

3. Spectral Region Below 1000 Å^(13c)

Prominent resonance bands appear at 924 Å and extend to 600 Å. Tanaka and Takamine (1942, 1943) measured three Rydberg series and five progressions of CO between 638 Å and 938 Å while Henning (1932) found 26 members of bands between 726 Å and 881 Å. Below 600 Å, no bands have been observed. For the continuum--which is most probably due to photoionization--extending from 880 Å (the first ionization potential) to 374 Å, Sun and Weissler (1955c) obtained an f -value of 2.8.

E. WATER VAPOR

1. Historical Survey^(19,25,27)

Water vapor is important because of its nearly universal appearance, and yet surprisingly little work has been done on it. The early work on the absorption spectrum of H_2O vapor in the ultraviolet by Leifson (1926), who observed a broad continuum between 1610 Å and 1870 Å and another beginning at 1392 Å, was extended by Henning (1932),

who observed two continua and a number of diffuse bands in the region from 600 Å to 1100 Å. Rathenau (1933) reported continuous absorption and bands between 500 Å and 1750 Å. Preston (1940) studied the Lyman- α line (1216 Å). Price (1936) established the first ionization potential at 985 Å by identifying two Rydberg series in the region from 1000 Å to 1250 Å. Wilkinson and Johnston (1950) reported absorption coefficients in the region from 1450 Å to 1850 Å. Other investigations were by Harrison et al. (1951); Johannin-Giles (1953); Watanabe and Zelikoff (1953), 1050 Å to 1850 Å; Watanabe and Jursa, 850 Å to 1100 Å; Astoin et al. (1953, 1956), 160 Å to 1100 Å; and Wainfan et al. (1955), 475 Å to 1000 Å. Watanabe et al. (1953b) undertook a detailed investigation in the area 1050 Å to 1860 Å.

2. Ultraviolet Spectral Region (19,22)

Twelve weak diffuse bands forming a progression in the region from 1250 Å to 1450 Å and a number of bands in the region from 1060 Å to 1250 Å appear. Price (1936) identified two Rydberg series in the latter region, one of them yielding an accurate value of the first ionization potential (at 987 Å). Watanabe and Zelikoff (1953) calculated f-values of 0.05 for the continuum 1150 Å to 1430 Å and 0.041 for the continuum 1430 Å to 1860 Å. They also reported that no pressure effect was observed except for a few bands. The most extensive measurement of absorption cross sections for this region was made by Astoin et al. (1953, 1956).

F. NITROGEN

1. Historical Survey^(3,27)

The absorption spectrum of molecular nitrogen was first studied by Lyman (1911) and later by Birge and Hopfield (1928). N_2 is practically transparent at all wavelengths longer than 1450 Å. No dissociative continua have been found, but in the far ultraviolet very intense ionization continua exist. In a detailed spectroscopic analysis Worley (1943), Tanaka and Takamine (1942) and others were able to group most of the strong and sharp resonance bands between 600 Å and 1000 Å into a Rydberg series converging on the first ionization potential at 796 Å and the Hopfield-Rydberg series converging on the limit at 661 Å. Absorption coefficient measurements were made by Clark (1952), 840 Å to 1000 Å; Weissler et al. (1952), 300 Å to 1300 Å; Curtis (1954), 150 Å to 1000 Å; Lee (1955), 900 Å to 1050 Å; Watanabe and Marmo (1956), 850 Å to 1000 Å; Astoin and Granier (1957), 125 Å to 1000 Å; and Watanabe (1961), a very detailed study of the region from 850 Å to 1000 Å, which showed a pressure effect at all wavelengths therein.⁽²⁰⁾

2. Spectral Region 800 Å to 1450 Å^(3,19,29)

This region is comprised primarily of the weak Lyman-Birge-Hopfield bands, which correspond to the forbidden transition $X^1\Sigma_g^+ \rightarrow ^1\Pi_g$. Tanaka (1955) suggests the appearance of other bands due to the transition $X^1\Sigma_g^+ \rightarrow C^3\Pi_u$. Weissler et al. (1952) have suggested a possible continuum in the region from 800 Å to 1300 Å, but more detailed studies--for example,

that of Watanabe (1961)--have failed to confirm its existence. Many strong, discrete bands forming numerous progressions occupy the area between 800 Å and 1000 Å. Lee (1955) found narrow areas of very low absorption coefficients in the region above 910 Å which agree with the atmospheric windows estimated by Hopfield (1946).

3 Spectral Region Below 800 Å (3,29)

From 300 Å to 800 Å the discrete band absorption superimposes a background of continuous absorption. Apparently, there are two ionization continua present: one adjoining the Worley-Jenkins series with a maximum near its long wavelength limit at 796 Å ($N_2^+ X^2 \Sigma_g^+$), and a much weaker continuum adjoining the Hopfield series with a separate maximum near its long wavelength limit at 661 Å ($N_2^+ B^2 \Sigma_u^+$). Weissler et al. (1952) calculated effective oscillator strengths of 3.0 for the stronger Worley-Jenkins continuum and 0.3 for the weaker Hopfield continuum.

G. ARGON⁽⁹⁾

There appears to be very little data available on absorption cross sections of argon. Wainfan et al. (1955) covered the region from 473 Å to 1100 Å, and Lee and Weissler (1955) covered the region from 240 Å to 1000 Å. The spectrum obtained by Lee and Weissler shows three sharp absorption edges: one (M_3) at 787 Å, the first ionization limit; another (M_2) at 778 Å; and a third (M_1) at 424 Å. A group of resonance absorption lines at longer wavelengths due to the transitions $3p \rightarrow nd$

and $3p \rightarrow ms$ were found,⁽⁹⁾ but the lines were much smaller than those in the continuous absorption. Large absorption coefficients between 420 \AA and 550 \AA may be due to autoionization near the (M_1) edge.

H. NITRIC OXIDE

1. Historical Survey^(13b,19,27)

The entire spectral region from 150 \AA to 2300 \AA has been studied by various investigators who have left few major gaps. Absorption cross sections in the region above 1400 \AA were measured by Mayence (1952) and above 1050 \AA by Marmo (1953, 1954). Later, Sun and Weissler (1955b) extended measurements down to 374 \AA . More recently, Granier and Astoin (1956) made measurements down to 150 \AA .

2. Spectral Region 1000 \AA to 2300 \AA ^(19,25)

The region from 1400 \AA to 2300 \AA consists of several systems of sharp bands which include the $\beta\gamma\delta\epsilon$ bands. The continuum below 1380 \AA appears rather flat and may be due to overlapping of more than one continua. Due to the complexity of the absorption spectrum in the region from 1300 \AA to 1700 \AA , it was not possible to identify extensive Rydberg series converging to the first ionization potential at 1343 \AA . Superimposed on the ionization continuum in the range 1000 \AA to 1340 \AA are a number of unidentified diffuse bands. For the region above 1400 \AA , Marmo (1953) with a resolution of 0.2 \AA , found a large apparent pressure effect, while below 1380 \AA , absorption cross section values were found

to be independent of pressure. For the region between 1200 Å and 1400 Å, Marmo (1953), by subtracting the ionization continuum and the bands from the total cross section curve, obtained a smooth dissociation continuum identified with the dissociation products $N(^2D)$ and $O(^3P)$. Watanabe found the onset of ionization to occur at 1343 Å. (27)

3. Spectral Region Below 1000 Å (13b,18,19,27)

Below 1000 Å, there appears to be at least two or three continua while the presence of diffuse bands in this area is indicated by the fluctuations in cross sections with wavelength. This region was found to be generally independent of pressure. The large absorption near 920 Å is probably due to the dissociation of NO caused by transitions from the ground state to the upper $^2\Pi$ state of the bands. (31)

Hagstrum (1951) observed the dissociative ionization reaction $NO \rightarrow N^+ + O^{-*}$ at 19.9 ev. Weissler (27) suggests the possibility that the corresponding peak at 620 Å is due to this process superimposed over the ionization continuum of Tanaka's (1942) γ -series limit I.P.₄.

I. NITROUS OXIDE

1. Historical Survey (18,19,25)

Early investigations of the vacuum ultraviolet absorption spectrum of N_2O were conducted by Leifson (1926), Sen-Gupta (1935), and Duncan (1936). Tanaka et al. (1957) found five Rydberg series in the region from 600 Å to 900 Å converging to three limits: 16.39, 16.55,

and 20.10 ev. Absorption coefficients have been reported by Watanabe et al. (1953b) in the region between 1050 Å and 2100 Å; by Walker and Weissler (1955) in the region between 675 Å and 950 Å, and recently by Romand (1962) down to 150 Å.

2. Spectral Region 1000 Å to 2200 Å^(25,27)

Most of the absorption of N₂O in the region from 1080 Å to 1215 Å may be attributed to an asymmetric continuum which apparently underlies the diffuse bands. Watanabe et al.⁽²⁵⁾ estimated an f-value of about 0.1 for this continuum which would indicate an allowed transition. From 1215 Å to 1380 Å there exists a well-defined continuum. The very strong absorption here is identified by Weissler⁽²⁷⁾ as the most characteristic feature of N₂O. Superimposed upon the symmetric continuum appear one prominent band around 1292 Å, assumed to be a Rydberg series member,⁽²⁵⁾ and several weak bands at higher wavelengths. Neglecting the sharp band, Watanabe's group (1953b) calculated an f-value of 0.367 for the continuum. Diffuse bands overlie the symmetrical continuum between 1380 Å and 1600 Å, for which an f-value of 0.0211 was measured.⁽²⁵⁾ The f-value suggests a fairly allowable transition. For the weaker continuum in the range 1600 Å to 2100 Å, an f-value of 0.0015⁽²⁵⁾ suggests a forbidden transition.

3. Spectral Region Below 1000 Å⁽¹⁸⁾

Walker and Weissler (1955) found the region from 675 Å to 950 Å to be mostly independent of pressure. They found an ionization

onset to occur at about 965 Å. Superimposed on the continua between 150 Å and 1000 Å are numerous bands which are narrow and sharp at shorter wavelengths and which become broader toward longer wavelengths.

J. NITROGEN DIOXIDE

1. Historical Survey (26)

There appears to have been few investigations of the vacuum ultraviolet absorption characteristics of NO₂. The absorption spectrum of NO₂ has been studied by Price and Simpson (1941) and by Mori (1954, 1955). The only data included in this study were reported by Watanabe et al. (1958) who made absorption cross section measurements in the region from 1050 Å to 2700 Å.

2. Ultraviolet Spectral Region (26)

Several strong diffuse bands in the region from 1080 Å to 1200 Å were found to fit a Rydberg series whose convergence limit of 11.62 eV was interpreted as the second ionization potential. Within the range 1300 Å to 1600 Å there are many sharp bands superimposed on a rather strong continuum. Rydberg series bands converging to the first ionization potential, 9.76 eV, are expected in this area but have escaped detection. There appears to be at least three dissociation continua here with dividing lines at about 1320 Å and 1500 Å. The region from 1600 Å to 2000 Å is dominated by continuous absorption with a number of relatively weak bands appearing. Although the k-values

throughout the entire range investigated were found to be generally independent of pressure, a distinct pressure effect was detected from 1850 Å to 2400 Å. where a continuum is apparent. Watanabe et al. (1958) inferred that this continuum was due to the varying concentration of N_2O_4 in the NO_2 sample used. At about 2450 Å, where the wings of two continua overlap, it is probable that the spectrum is complicated by predissociation.

K AMMONIA

1 Historical Survey (19,25)

The absorption spectrum of NH_3 in the vacuum ultraviolet was thoroughly studied by Duncan (1935, 1936). He confirmed the earlier observations of Leifson (1926) and Dixon (1933) in the longer wavelength region and extended their investigation down to 850 Å. Duncan (1935) analyzed the resonance bands which appear above 1150 Å. Absorption cross sections in the region from 1700 Å to 2200 Å have been published by Tannenbaum et al. (1953). Watanabe et al. (1953b) reported k-values between 1060 Å and 2200 Å, and Sun and Weissler (1955a) reported cross sections for the region from 374 Å to 1306 Å.

2 Ultraviolet Spectral Region (13a,19,25)

The structure of the absorption contour suggests the existence of two ionization continua: a stronger one which peaks at about 730 Å, and a weaker one which peaks at about 1130 Å. These two

maxima correspond to the ionization limits of the outer electrons of NH_3 . Sun and Weissler (1955a) report a total f-value of 5.9 for this region. The region above 1300 Å was included in the study made by Watanabe et al (1953b). For the continuum between 1200 Å and 1550 Å they estimated an f-value of 0.02; and for the continuum between 1600 Å to 2200 Å, they calculated an f-value of 0.030.

L METHANE

1. Historical Survey (19,25)

Leifson (1926), Rose (1933), and Duncan and Howe (1934) were earlier investigators of the vacuum ultraviolet absorption spectrum of CH_4 . Absorption coefficients in the region from 1370 Å to 1455 Å were measured by Wilkinson and Johnston (1950). Later, Moe and Duncan (1952) and Watanabe et al (1953b) reported measurements down to 1050 Å. More recently, Ditchburn (1955) and Sun and Weissler (1955a) extended measurements to 400 Å.

2. Ultraviolet Spectral Region (13a,27)

As it was expected from the symmetrical structure of the CH_4 molecule, the absorption is continuous with superimposed band structure appearing only in a few regions. Only below 800 Å can absorption be wholly accounted for by photoionization. Sun and Weissler (1955a) reported a total f-value of 6.1 pertaining to transitions of 2p-electrons. They further report that the first ionization potential occurs at about 960 Å.

TABLE 1

SUMMARY OF ABSORPTION CROSS SECTION STUDIES
BY INVESTIGATORS

(Spectral Region A)

Gas	Watanabe et al.	Weissler et al.	Romand	Other
O ₂	840-1900	300-1300		Aboud <u>et al.</u> 100-870 Ditchburn & Young 1850-2500
O ₃	1050-2200			Ogawa & Cook 525-1300 Inn <u>et al.</u> 2000-3000
CO ₂	1050-1750	350-1300	150-750	
CO	1050-1650	350-1300		
H ₂ O	850-1850		150-1100	
N ₂	850-1000	300-1200	150-950	
A		350-825		
NO	1065-2300	375-1300	150-1000	
N ₂ O	1080-2160	675-950	150-1000	
NO ₂	1080-2700			
NH ₃	1060-2200	375-1300		
CH ₄	1065-1610	375-1300		

TABLE 2

ABSORPTION COEFFICIENTS OF O₂ $\lambda=112 \text{ \AA}$ to $\lambda=866 \text{ \AA}$ REF: A.A. Aboud, J.P. Curtis, R. Mercure, and W.A. Rense, J. Opt. Soc. Am. 45, 767. (1955)

k in Reciprocal Centimeters

λ	k	λ	k
112	5	553.0	960
125	20	617.0	970
155	200	630.8	940
276.3	210	634.0	970
304.1	610	694.1	1080
377.1	470	700.9	980
407.2	520	704.2	1080
476.5	680	735.1	860
503.8	850	755.0	480
520.7	1030	866.3	360
552.0	990		

TABLE 3

 ABSORPTION COEFFICIENTS OF O₂
 $\lambda=303 \text{ \AA}$ to $\lambda=1306 \text{ \AA}$
Ref: G.L. Weissler and P. Lee, J. Opt. Soc. Am. 42, 200 (1952)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
303.8	530	685.5	720	977.0	470
429.6	890	685.8	720	988.8	110
430.0	930	702.3	710	989.8	170
525.8	800	702.9	820	990.2	150
529.5	842	703.8	800	990.8	170
529.8	830	718.5	600	991.6	180
537.8	860	745.8	710	999.5	110
538.2	700	747.0	760	1025.7	43
539.2	770	771.9	510	1036.3	500
539.5	760	772.4	640	1037.0	540
539.8	740	776.0	490	1084.0	100
574.6	840	796.7	680	1110.0	770
580.4	750	832.9	670	1134.2	59
581.0	720	833.3	380	1134.4	59
584.3	550	833.7	340	1135.0	82
599.6	780	835.1	360	1152.1	120
600.6	790	835.3	300	1175.7	410
616.3	740	877.8	490	1199.5	66
617.0	810	886.6	440	1200.7	83
644.1	690	904.0	540	1206.4	872
644.8	750	904.1	590	1217.6	54
645.2	720	904.5	420	1243.2	909
660.4	780	915.96	280	1302.2	24
671.4	720	916.01	240	1304.9	24
672.3	670	916.7	240	1306.0	7

TABLE 4

ABSORPTION COEFFICIENTS OF O₂ $\lambda=840 \text{ \AA}$ to $\lambda=1900 \text{ \AA}$

REF: See end of Table

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
(1) 840 to 1100 \AA					
841.9	240	860.3	200	877.8	320
843.6	310	862.1	190	878.7	280
844.6	250	862.6	180	879.0	260
845.3	260	863.4	200	879.5	220
846.1	410	863.7	330	880.1	180
847.1	250	864.3	210	880.6	170
847.4	310	864.7	240	881.0	160
848.0	210	865.1	320	881.7	230
849.1	210	865.6	210	882.1	140
849.7	230	866.0	190	882.5	170
850.2	250	866.2	190	883.3	150
850.6	260	866.9	230	883.5	140
851.0	240	867.4	160	884.1	150
851.5	220	867.9	170	884.5	160
852.2	230	868.5	190	885.0	230
852.8	320	869.0	170	885.2	350
853.2	340	869.5	200	885.8	400
853.5	270	869.9	240	886.5	260
854.1	240	870.3	250	887.2	180
854.5	260	871.4	230	887.7	150
854.9	190	871.7	270	888.1	150
855.3	200	872.1	320	888.3	140
855.7	190	872.9	190	889.0	140
856.1	220	873.6	180	889.6	150
856.4	220	873.8	200	889.8	140
857.0	240	874.3	210	890.3	180
857.9	200	875.1	150	891.2	240
858.1	210	875.8	170	891.5	300
858.5	250	876.2	200	891.8	250
859.5	180	876.7	230	892.4	220
859.8	180	877.4	210	893.4	230

TABLE 4 (continued)

ABSORPTION COEFFICIENTS OF O₂ $\lambda=840 \text{ \AA}$ to $\lambda=1900 \text{ \AA}$

REF. See end of Table

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
894.6	260	915.6	110	931.0	390
894.8	220	916.0	110	931.4	310
895.5	170	916.3	150	931.7	330
896.2	190	917.0	500	932.1	370
896.5	200	917.2	490	932.5	780
897.1	190	917.8	420	933.3	210
897.9	180	918.7	200	933.8	150
898.2	140	919.0	160	934.5	120
898.6	150	919.2	130	934.9	110
899.6	160	919.5	110	935.6	86
900.2	210	920.0	100	935.8	81
900.7	350	920.2	92	936.1	77
901.3	360	920.4	90	936.4	80
901.7	310	921.2	93	936.9	77
902.3	230	921.4	100	937.1	98
902.8	210	921.6	110	937.6	96
903.7	220	922.2	150	937.8	100
904.1	210	922.5	170	938.1	130
904.6	170	922.8	240	938.8	850
905.5	120	923.2	270	939.3	1150
905.8	120	923.5	240	940.3	460
906.7	110	924.0	360	941.1	220
907.4	110	924.3	400	941.6	120
907.7	120	924.7	490	942.2	95
908.1	120	925.1	400	943.3	100
908.6	170	925.5	300	943.5	100
909.6	430	926.0	210	943.8	67
910.4	410	926.8	120	944.1	75
910.6	390	927.3	110	944.5	72
911.2	200	927.8	98	944.8	65
911.5	150	928.1	82	945.2	79
911.8	150	928.8	100	946.0	88
912.2	130	929.6	100	946.7	180
913.5	140	930.0	94	947.4	940
914.2	120	930.2	210	947.8	1400
914.8	200	930.7	640	948.1	1400

TABLE 4 (continued)

ABSORPTION COEFFICIENTS OF O₂ $\lambda=840 \text{ \AA}$ to $\lambda=1900 \text{ \AA}$

REF: See end of Table

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
948.4	600	965.6	880	982.6	760
948.7	430	966.0	970	983.3	850
949.1	340	967.3	280	983.8	390
949.7	140	967.6	200	984.6	120
950.9	93	967.9	120	985.2	120
951.3	81	968.3	94	985.8	180
951.6	73	969.2	71	986.1	170
951.9	92	969.9	69	986.6	160
952.3	87	970.2	68	986.9	150
952.6	88	970.4	65	987.5	110
952.8	89	971.0	68	988.0	80
953.6	85	971.4	88	988.5	60
954.8	120	972.0	180	989.3	53
955.6	960	972.5	820	989.6	40
955.9	1200	973.4	770	990.1	63
956.5	740	974.1	210	990.6	60
956.7	750	974.5	150	991.2	53
956.9	870	974.8	190	991.7	47
957.3	690	975.1	440	992.0	55
957.8	340	975.5	560	992.9	450
958.4	230	975.9	420	993.3	660
958.8	120	976.2	340	993.5	560
959.4	73	976.7	160	994.2	360
959.7	70	977.3	35	994.4	220
960.0	74	977.7	74	994.8	130
960.7	160	977.9	78	995.2	78
961.7	230	978.5	73	995.7	50
962.0	350	979.2	87	996.1	47
962.3	270	979.5	86	996.5	41
962.8	130	979.8	95	997.2	39
963.1	130	980.1	85	997.6	39
963.6	230	980.5	58	998.0	42
964.1	260	981.3	66	998.4	42
964.8	460	981.7	100	998.8	46
965.4	820	982.1	160	999.3	44

TABLE 4 (continued)

ABSORPTION COEFFICIENTS OF O₂ $\lambda=840 \text{ \AA}$ to $\lambda=1900 \text{ \AA}$

REF: See end of Table

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
999.7	38	1015.8	47	1034.9	45
1000.0	40	1016.0	32	1035.5	18
1000.7	38	1016.4	37	1036.5	14
1000.9	41	1016.9	29	1036.9	26
1001.5	47	1017.2	43	1037.2	18
1001.9	38	1017.8	26	1038.0	51
1002.4	41	1018.3	41	1038.2	29
1002.6	55	1018.6	34	1038.8	19
1003.2	120	1018.8	29	1039.1	26
1004.0	170	1019.4	38	1039.4	48
1004.3	150	1020.4	32	1040.5	36
1004.6	170	1020.8	43	1040.9	26
1005.0	83	1021.1	35	1041.1	24
1005.5	76	1021.6	44	1041.6	31
1005.8	57	1021.9	41	1041.9	33
1006.2	44	1022.4	35	1042.5	29
1006.4	43	1023.4	50	1042.9	16
1006.8	37	1023.8	46	1043.5	7.2
1007.3	40	1024.3	38	1043.8	3.3
1007.6	44	1024.6	27	1044.3	4.2
1007.9	49	1025.3	48	1044.9	4.4
1008.3	48	1025.7	50	1045.3	11
1008.8	43	1026.6	34	1045.7	13
1009.1	38	1027.1	35	1046.1	14
1009.4	41	1027.8	29	1046.6	22
1010.0	36	1028.2	18	1047.1	69
1010.5	32	1028.8	25	1047.8	38
1011.4	35	1029.3	51	1048.6	64
1011.6	32	1030.2	22	1048.9	65
1012.3	29	1030.8	39	1049.5	67
1012.5	31	1031.0	40	1050.1	11
1013.0	34	1031.3	39	1050.6	15
1013.5	36	1031.9	32	1051.1	30
1013.9	30	1032.3	27	1051.9	22
1014.2	37	1033.1	29	1052.4	58
1014.5	42	1033.6	24	1054.0	21
1015.4	46	1034.3	43	1054.2	16

TABLE 4 (continued)

ABSORPTION COEFFICIENTS OF O_2 $\lambda=840 \text{ \AA}$ to $\lambda=1900 \text{ \AA}$

REF. See end of Table

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
1054.6	18	1067.0	6.4	1082.3	21
1054.8	53	1067.6	4.4	1083.0	51
1055.3	19	1067.9	4.3	1084.1	29
1055.6	8.5	1068.5	3.4	1084.5	59
1056.4	11	1068.9	3.2	1085.2	72
1056.8	11	1069.9	3.6	1086.0	16
1057.0	14	1070.7	6.2	1086.3	10
1058.0	22	1071.4	21	1086.8	7.3
1058.3	28	1072.2	20	1087.1	9.9
1058.7	17	1072.7	29	1087.5	21
1059.6	31	1073.2	29	1088.6	14
1060.1	25	1073.5	39	1089.9	14
1060.6	23	1073.9	54	1090.5	11
1060.9	31	1074.3	24	1091.1	3.0
1061.1	16	1074.6	20	1091.8	2.1
1061.4	18	1075.2	8.7	1092.4	2.3
1061.7	31	1075.9	5.8	1092.8	2.7
1062.0	16	1076.6	5.8	1093.5	2.8
1062.6	11	1077.0	3.7	1094.0	3.5
1063.4	20	1077.4	12	1094.7	1.8
1063.6	35	1077.7	11	1096.0	3.5
1064.2	82	1078.0	23	1097.2	7.3
1064.8	47	1078.4	15	1097.6	5.1
1065.1	50	1078.8	21	1098.0	5.7
1065.7	77	1079.7	59	1099.5	6.7
1066.4	92	1081.4	41		
1066.7	57	1081.8	62		

(2a) 1100 to 1166 \AA (curve)(2b) 1100 to 1166 \AA (windows superimposed on curve)

1107.8	0.32	1110.5	0.48	1144.3	0.65
1108.3	0.11	1126.9	0.53	1145.3	0.70
1108.9	0.25	1142.8	0.26	1157.0	0.51
1109.9	0.35	1143.0	0.33	1157.4	0.60

TABLE 4 (continued)

ABSORPTION COEFFICIENTS OF O₂
 $\lambda=840 \text{ \AA}$ to $\lambda=1900 \text{ \AA}$

REF: See end of Table

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
(3) 1166 to 1407 \AA (; represents superimposed window data from reference 2b.)					
+1166.1	0.52	1206	480	1240.5	4.9
+1166.8	0.27	1206.5	460	1241.5	879
+1167.2	0.35	1208.5	330	1243.5	940
1168	1.0	1209	130	1245	95
1169	2.1	1210	87	1247	56
1172	44	1211	24	1249.5	39
1174.5	38	1213	17	1252	28
1175	36	1213.5	11	1254.5	23
1176	24	+1214.8	0.70	1256	19
1177	23	+1215.0	0.50	1257	16
1178	11	+1215.7	0.27	1259.5	12.5
1180.5	5.6	+1216.5	0.40	1260.5	10.8
1181.5	11	+1217.3	0.60	1262	11.9
1182.5	6.1	1217.5	0.80	1263.5	9.2
1184	7.1	1218.5	2.5	1264.5	6.5
1186	3.9	1220	5.2	1266	4.9
+1186.6	0.35	1221	5.9	1269	3.2
+1187.1	0.18	1222	11	1271	1.8
+1187.8	0.25	1223.5	7.0	1274	2.5
+1188.3	0.39	1225	13	1277	4.1
+1188.9	0.64	1228.5	11	1279.5	6.7
1190	6.2	1229	12	1283.5	9.8
1191.5	5.0	1230	10	1287	12.7
1192.5	10.1	1231.5	13	1290.5	14.6
1193	6.7	1232.5	14	1293	15.7
1194.5	12.7	1233.5	20	1296.5	14.8
1195.5	16.5	1234.5	20	1299	14.0
1198	32	1235	12.3	1302	11.9
1200	51	1236	14	1306	9.6
1201.5	90	1237.5	13	1309	13.9
1202	104	1238.5	9.3	1312.5	19.4
1203.5	230	1239.5	8.1	1317	29.6
1205	500	1240	6.3	1321.5	42.9

TABLE 4 (continued)

ABSORPTION COEFFICIENTS OF O₂ $\lambda=840 \text{ \AA} \text{ to } \lambda=1900 \text{ \AA}$

REF: See end of Table

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
1325	55.0	1349	155	1378	342
1329	62.1	1351	191	1384	354
1333.5	61.6	1355	191	1391.5	359
1336.5	59.1	1361	220	1394	366
1339.5	60.3	1366	259	1400.5	370
1343	75	1369	303	1405	375
1345	93	1375	332		
(4) 1407 to 1452 \AA					
1407.4	390	1420.2	393	1437.8	394
1408.6	388	1423.0	393	1440.9	393
1410.5	394	1427.7	394	1433.5	389
1412.9	392	1430.0	394	1446.0	386
1414.8	391	1432.9	394	1450.3	385
1416.3	391	1436.2	393	1452.1	383
(5) 1452 to 1751 \AA					
1455	368	1532	249	1602	125
1457.5	365	1537.5	233	1608	112
1460	361	1541.5	227	1613	104
1463	355	1544.5	219	1620.5	92
1467.5	355	1547	217	1623.5	89
1473.5	350	1551	209	1628.5	80
1479	338	1555.5	204	1633.5	75
1486	324	1562.5	194	1636.5	72
1489	318	1569.5	175	1638.5	69
1491.5	319	1572	171	1644	63
1495	307	1577.5	165	1648	60
1499	304	1581	158	1654	54
1504	294	1585.5	155	1658.5	49
1510.5	285	1589	144	1663	46
1517	274	1591	137	1667	42
1522.5	266	1596	133	1671	39

TABLE 4 (continued)

ABSORPTION COEFFICIENTS OF O₂ $\lambda=840 \text{ \AA}$ to $\lambda=1900 \text{ \AA}$

REF. See end of Table

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
1677.5	35	1705	20.3	1737	10.6
1682	32	1712	18.2	1742	9.5
1687	30	1717	16.4	1747	8.3
1689	26.5	1722	15.0	1749	7.2
1697	24.0	1727	13.6	1751	6.5
1702	21.8	1732	11.9		

(6) 1751 to 1900 \AA (curve)Reference: K. Watanabe, et al.:

- (1) 840 to 1100 \AA : Hawaii Institute of Geophysics, Contr. No. 33, Dec. 1961.
- (2a,b) 1100 to 1166 \AA , curve, 1100 to 1166 \AA , windows, + (1166 to 1217 \AA), windows. "U.V. Absorption Processes in Upper Atmosphere", Advances in Geophysics, 5, 181-221 (1958).
- (3,5,6) 1166 to 1407 \AA ; 1452 to 1751 \AA ; 1751 to 1900 \AA , curve: AFCRC Tech. Rep. 53-23, Geo. Res. Papers No. 21, June 1953.
- (4) 1407 to 1452 \AA : J. Chem. Phys., 25, 965 (1956).

TABLE 5

ABSORPTION COEFFICIENTS OF O₃ $\lambda=526 \text{ \AA}$ to $\lambda=1305 \text{ \AA}$ REF: M. Ogawa and G.R. Cook, J. Chem. Phys. 28, 173 (1958)

k in Reciprocal Centimeters

λ	k	λ	k
526	817	773	940
539	864	797	803
555	827	834	673
581	862	879	503
600	949	916	352
617	935	980	257
645	100	990	215
672	949	1085	248
686	980	1135	340
703	111	1216	614
718	119	1243	288
749	985	1305	234

TABLE 6

ABSORPTION COEFFICIENTS OF O₃ $\lambda=2000 \text{ \AA}$ to $\lambda=3000 \text{ \AA}$ REF: E.C.Y. Inn and Y. Tanaka, "Ozone Absorption Coefficients",
Advances in Chemistry Series No. 21, 1959.

k in Reciprocal Centimeters (Base e)

λ	k	λ	k	λ	k	λ	k
2002	8.61	2292	113	2527	299	2742	158
2012	8.52	2302	122	2539	309	2746	160
2022	8.36	2312	130	2543	299	2752	153
2032	8.54	2322	140	2553	311	2762	140
2042	8.82	2332	149	2562	304	2772	131
2052	9.26	2342	159	2566	292	2782	121
2062	10.0	2352	170	2571	302	2792	111
2072	11.2	2362	180	2575	299	2802	100
2082	12.0	2372	192	2579	295	2812	91.4
2092	13.4	2382	198	2587	306	2822	83.8
2102	14.7	2392	208	2597	290	2830	81.1
2112	16.5	2400	216	2604	295	2842	70.0
2122	18.6	2402	219	2617	279	2852	63.3
2132	21.2	2412	228	2624	283	2862	56.0
2142	23.7	2422	237	2635	262	2872	51.1
2152	26.9	2432	246	2643	272	2882	44.4
2162	30.2	2438	256	2650	258	2892	40.0
2172	33.6	2444	258	2654	256	2902	35.7
2182	38.0	2452	267	2662	249	2912	31.1
2192	42.1	2458	272	2669	235	2922	28.3
2202	48.4	2463	272	2675	237	2932	24.6
2212	53.0	2472	281	2682	223	2942	21.7
2222	58.5	2478	286	2692	220	2952	19.2
2232	65.4	2482	283	2695	218	2962	16.7
2242	71.2	2490	292	2702	205	2972	14.6
2252	79.0	2492	292	2712	194	2982	12.7
2262	86.6	2500	299	2718	194	2992	11.0
2272	94.2	2508	292	2722	184		
2282	103	2519	306	2732	174		

TABLE 7

 ABSORPTION COEFFICIENTS, k , IN RECIPROCAL CENTIMETERS
 FOR CARBON DIOXIDE AT VARIOUS WAVELENGTHS *

λ A	k	λ A	k	λ A	k
165	460	247	560	383	730
165.5	340	249	700	389	570
166	160	251	760	395	650
167	**	264	600	398	650
168	**	266	720	401	500
171	330	277	640	402	600
172	390	278	740	403	680
173	500	289	680	408	500
177	220	290.2	690	411	570
178	180	290.5	500	416	460
180	380	291	420	419	510
181	400	292	600	420	460
183	640	293	680	427	460
185	560	293.7	500	429	510
186.5	320	294	220	430	530
188.5	620	295	800	431	540
189.5	480	296	500	426	640
193	540	297	680	438	660
194.8	400	298	640	440	600
195	370	299	680	442	700
196	640	301	440	443	760
197	740	302	760	446	660
201	520	304	380	459	680
207	460	304.5	340	479	650
210	440	312.5	400	483	680
211	480	317	370	500	820
212	660	322	440	504	920
216	640	327	480	505	1020
217	620	335	610	507	820
218	740	344	650	508	740
221	480	346.5	720	526	720
224	700	352	880	554	1160
230.5	540	354	670	555	840
231	580	359	810	620	760
234	500	361	750	633	940
235.2	660	366	800	645	615
236.5	600	368	750	653	600
238	520	369	720	685	500
238.6	720	370	680	694	410
241	680	372	630	701	420
245	600	373	630	710	520
246	580	377	690	733	390

*J. Romand, Laboratoires de Bellevue, France, Private Communication (July 1962)

**No significant absorption for the pressures and pathlengths employed.

TABLE 8

ABSORPTION COEFFICIENTS OF CO₂ $\lambda=373 \text{ \AA}$ to $\lambda=1306 \text{ \AA}$ REF: H. Sun, G.L. Weissler; J. Chem. Phys., 23, 1625 (1955)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k	λ	k
373.8	830	616.3	910	764.4	1530	923.2	3140
374.3	720	617.1	940	765.1	2010	923.7	1370
434.0	700	635.2	800	771.5	1040	924.3	1500
434.3	700	644.1	910	771.9	720	955.3	1980
507.4	880	644.6	890	772.4	640	977.0	700
507.7	830	644.8	960	773.0	780	979.9	750
508.2	800	645.2	960	776.0	620	989.8	270
509.9	830	660.3	780	787.7	720	991.5	1260
525.8	800	671.4	910	790.1	350	1084.0	240
537.8	880	671.8	860	796.7	480	1122.3	670
538.4	880	672.0	960	799.7	860	1127.8	2580
539.1	800	672.9	830	799.9	750	1134.4	560
539.5	830	673.8	780	832.8	190	1135.0	530
539.9	830	685.0	530	833.3	320	1183.0	0
553.3	1070	685.5	780	833.7	240	1184.5	0
554.5	940	685.8	700	835.1	130	1199.5	0
555.0	970	686.3	640	835.3	94	1200.2	0
555.1	940	702.3	1100	903.6	880	1200.7	0
555.3	1020	702.9	620	904.5	880	1243.3	0
580.4	800	703.9	530	915.9	2040	1302.2	160
581.0	830	718.6	510	916.0	1390	1304.9	61
582.2	750	745.8	830	916.7	940	1306.0	43
597.8	960	747.0	460	922.5	3030		
599.6	830	764.3	910	923.0	1070		

TABLE 9

ABSORPTION COEFFICIENTS OF CO₂ $\lambda=1064 \text{ \AA}$ to $\lambda=1752 \text{ \AA}$ REF: K. Watanabe, et al., AFCRC Tech. Rep. No. 53-23, Geo. Res. Paper No. 21, (1953)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
1064	250	1124	1630	1183	2.6
1068	430	1126	2470	1185.5	1.89
1071	480	1128.5	2520	1189.5	0.75
1074.5	450	1132	640	1191	0.99
1076.5	220	1136.5	340	1192.5	1.15
1079.5	350	1138	182	1197	0.94
1082.5	330	1142	510	1198.5	0.99
1084	200	1146	74	1201.5	1.22
1087.5	3620	1149	104	1203	1.34
1089.5	470	1151.5	56	1206	1.24
1092	200	1152	102	1208.5	1.46
1092.5	240	1155	17	1209.5	1.69
1094	156	1156	73	1210.5	1.54
1096	154	1158	108	1211.5	1.64
1099	230	1159	13.5	1213	1.83
1101	320	1161.5	9.1	1215.6	1.97
1102.5	310	1163.5	6.8	1218.5	1.99
1104.5	330	1165.5	17.0	1221	2.10
1106.5	410	1167.5	16.6	1223	2.15
1108	600	1168.5	6.8	1224	2.44
1110	1020	1169.5	5.1	1226.5	2.78
1111	900	1171	3.2	1230	2.83
1114.5	1220	1172.5	3.6	1235.5	3.4
1116	1630	1173.5	6.8	1239.5	4.2
1118	3660	1176	6.7	1243.5	5.3
1119	4350	1178	1.37	1246	4.3
1120	3780	1179.5	1.33	1247.5	5.5
1121.5	1900	1181	1.22	1250	7.2

TABLE 9 (continued)

 ABSORPTION COEFFICIENTS OF CO₂
 $\lambda=1064 \text{ \AA}$ to $\lambda=1752 \text{ \AA}$

 REF: K. Watanabe, et al., AFCRC Tech. Rep. No. 53-23, Geo. Res.
 Paper No. 21, (1953)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
1251.5	7.1	1305.5	22	1372	17.8
1253.5	7.5	1307.5	16.2	1373	18.3
1255.5	5.7	1311.5	17.5	1375	16.1
1257.	5.8	1313	31	1377	15.0
1260	10.8	1315.5	25.8	1378	15.6
1261.5	10.1	1319.5	19.5	1381	20.4
1264	9.2	1323.5	25	1383	18.1
1267	7.7	1325.5	31	1384.5	17.3
1268.5	12.4	1327.5	27	1386.5	16.7
1271	14.3	1331.5	20	1388	15.4
1273.5	12.3	1334.5	25	1391.5	15.3
1276.5	8.9	1336.5	32	1394.5	15.7
1278	11.2	1339.5	24	1397	13.5
1279	14.4	1343	19.1	1398	14.6
1281	17.2	1344.5	23	1399.5	16.2
1283	18.1	1346	19.2	1401	17.0
1284.5	15.1	1348	29	1403	17.4
1286.5	11.4	1351.5	22	1405	15.5
1287.5	11.2	1353.5	17.1	1406.5	14.3
1288.5	12.9	1354.5	17.4	1408	15.4
1289.5	14.6	1356.5	16.7	1409	15.5
1290.5	22	1357.5	18.1	1411	16.8
1291.5	25	1360	27	1413.5	16.1
1293.5	23	1362.5	21	1415.5	16.0
1295.5	17.3	1364	17.0	1416.5	16.1
1297	13.7	1366.5	17.4	1418.0	17.3
1300	15.9	1368	17.4	1420.5	15.6
1302.5	34	1370	21	1421.5	18.1

TABLE 9 (continued)

ABSORPTION COEFFICIENTS OF CO₂ $\lambda=1064 \text{ \AA}$ to $\lambda=1752 \text{ \AA}$ REF: K. Watanabe, et al., AFCRC Tech. Rep. No. 53-23, Geo. Res. Paper No. 21, (1953)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
1423.4	18.2	1480.5	15.6	1536	10.5
1425.5	18.3	1482.5	17.1	1538.5	9.8
1428	14.5	1484.5	15.4	1540.5	10.7
1430.5	14.3	1488	14.5	1543	11.6
1433.5	16.0	1490.5	14.0	1546	9.7
1435.5	16.8	1493	16.3	1547	10.0
1437	17.3	1495.5	16.1	1548.5	10.2
1438.5	15.0	1496.5	15.9	1550	8.5
1441.5	14.9	1498.5	15.0	1551.5	8.6
1444	16.0	1501	12.5	1553.5	8.4
1446.5	17.4	1503	14.9	1554.5	10.0
1448	16.9	1506	15.9	1556	9.9
1451	15.7	1507.5	14.9	1558.5	9.2
1453	14.7	1509	14.7	1560	9.3
1455.5	15.0	1512	12.6	1562	8.1
1457	16.5	1514.5	13.0	1563	7.8
1458.5	18.5	1516	13.9	1566.5	7.7
1461	15.9	1517	14.6	1568.5	7.9
1463.5	13.5	1518.5	13.6	1571.5	7.9
1465	13.7	1519.5	13.9	1574	6.4
1466	15.0	1521	12.5	1577	5.8
1468	17.8	1523	11.7	1578.5	6.1
1469.5	18.0	1524.5	11.8	1580.5	6.6
1471.5	16.2	1526.5	12.0	1583.5	7.1
1473.5	14.1	1528.5	11.9	1585.5	6.6
1475	14	1530.5	12.8	1587.5	5.9
1477.5	15.8	1532	12.5	1588.5	5.7
1479	14.9	1533.5	11.5	1590	5.0

TABLE 9 (continued)

ABSORPTION COEFFICIENTS OF CO₂ $\lambda=1064 \text{ \AA}$ to $\lambda=1752 \text{ \AA}$ REF: K. Watanabe, *et al.*, AFCRC Tech. Rep. No. 53-23, Geo. Res. Paper No. 21, (1953)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
1591	4.8	1643	2.30	1690	0.89
1593.5	4.6	1644.5	2.25	1691	0.93
1596	6.0	1645.5	2.33	1693.5	0.73
1599	5.0	1647.5	2.15	1695.5	0.79
1602.5	4.4	1649.5	1.76	1697	0.66
1604.5	4.5	1650.5	1.77	1699	0.63
1606.5	3.9	1654	1.47	1702	0.57
1608	3.7	1656.5	1.63	1705.5	0.51
1610.5	4.4	1657.5	1.60	1708	0.52
1612	4.2	1660	1.74	1710	0.51
1613.5	4.1	1663	1.66	1712.5	0.39
1616	4.1	1665	1.42	1715	0.47
1616.5	3.7	1667.5	1.41	1717	0.33
1618	3.5	1669	1.55	1719.5	0.43
1621	3.3	1670.5	1.25	1721.5	0.34
1623.5	2.7	1672	1.27	1724	0.39
1625.5	3.3	1673.5	1.45	1727	0.30
1628.5	3.2	1674.5	1.51	1729.5	0.28
1630.5	3.2	1677.5	1.43	1732	0.25
1631.5	2.69	1679.5	1.25	1734.5	0.26
1634	2.35	1681.5	1.15	1737	0.21
1634.5	2.35	1683.5	0.97	1740	0.22
1636.5	2.23	1684	0.78	1742.5	0.22
1638.5	2.27	1685.5	0.97	1747	0.17
1640.5	2.17	1686.5	0.90	1752	0.15
1641.5	2.18	1688.5	0.72		

TABLE 10

ABSORPTION COEFFICIENTS OF CO

 $\lambda=373 \text{ \AA}$ to $\lambda=1306 \text{ \AA}$ REF: H. Sun, G.L. Weissler; J. Chem. Phys., 23, 1626 (1955)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
373.8	430	629.4	560	790.1	430
374.3	350	635.2	590	796.7	1230
434.0	460	644.1	430	799.7	510
434.3	460	644.6	430	799.9	460
507.4	510	644.8	430	832.8	510
507.7	460	645.2	460	833.3	480
508.2	460	660.3	460	834.5	480
509.6	510	671.4	670	835.1	380
525.8	510	671.6	510	903.6	510
529.5	480	671.8	480	904.5	480
529.7	530	672.0	460	915.9	620
529.9	510	672.9	530	916.0	1290
537.8	510	685.0	430	916.7	230
538.3	510	686.3	430	922.5	0
539.1	510	702.3	460	923.0	940
539.5	510	702.9	480	923.2	620
539.9	530	703.9	460	923.7	300
553.3	560	718.6	510	924.3	300
554.5	510	745.8	530	955.3	0
555.3	480	747.0	480	979.9	0
574.7	480	763.3	530	1006.0	0
580.4	480	764.4	780	1135.0	0
581.0	480	765.1	560	1152.2	0
582.2	480	771.5	460	1175.5	0
597.8	510	772.4	590	1184.5	0
599.6	480	773.0	620	1276.7	0
616.3	530	776.0	670	1306.0	0
617.1	530	787.7	590		

TABLE 11

 ABSORPTION COEFFICIENTS, k , IN RECIPROCAL CENTIMETERS
 FOR WATER VAPOR AT VARIOUS WAVELENGTHS*

λ A	k	λ A	k	λ A	k	λ A	k
194.8	100	337	600	429	720	810	980
196	200	338	620	434	800	812	940
197	400	340	620	436	800	820	940
200	500	340.5	620	438	840	823	1060
201	340	344	660	440	820	832.9	1040
204	360	346	620	442	800	833.7	960
210	120	346.5	680	446	820	835.1	600
214	540	352	660	468	720	836.3	680
216	420	358	660	505	640	864	540
217	360	359	760	508	300	866	620
230.5	180	360	740	509	780	868	540
231	500	361	760	526	760	871	840
234.4	180	364	680	528	900	876	780
234.8	320	366	700	535	700	881	460
235.2	280	367	700	539	600	886	760
238.6	1060	368	640	541	680	892	780
241	220	369	640	547	540	898	300
244	340	370	680	550	560	912	640
245	240	371	620	554.5	720	935	520
246	340	372	680	572	600	963	420
249	520	373	640	587	460	975	260
264	480	374	600	601	900	1018	860
278	500	377	660	602	990	1042	380
280	380	383	660	603	580	1085	240
289	880	389	600	608	840		
290.2	760	390	640	629	660		
291	860	393	700	630	780		
293.7	860	394	760	660	920		
295	940	395	700	701	400		
296	740	398	700	715	920		
297	860	401	720	717	920		
299	1040	402	700	730	720		
310	520	403	740	733	840		
312.5	540	408	760	740	560		
322	580	410	820	743	840		
325	620	411	780	749	380		
328.5	600	416	740	750	1000		
333	600	419	720	754	740		
335	620	427	780	790	1320		

*J. Romand, Laboratoires de Bellevue, France. Private Communication (July 1962).

TABLE 12

ABSORPTION COEFFICIENTS OF H₂O $\lambda=850 \text{ \AA}$ to $\lambda=1855 \text{ \AA}$

REF: (a) K. Watanabe, Adv. In Geophys. 5, 199 (1958)
 (b) K. Watanabe, *et al.*, AFCRC Tech Rep. 53-23, Geo. Res. Paper 21, (1953)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
(a) 850 \AA to 1065 \AA (Curve)					
(b) 1065 \AA to 1855 \AA					
1065	88	1114.5	650	1165	78
1066	91	1116.5	400	1166	98
1068.5	65	1118.5	161	1168	146
1070.5	78	1120.5	440	1169	153
1071.5	115	1122	520	1170.5	198
1073.5	188	1123.5	470	1172	230
1075.5	260	1125.5	440	1173	230
1077	188	1127	590	1175.5	200
1080.5	96	1128.5	530	1178	138
1081.5	130	1132.5	157	1179	104
1083	141	1135	114	1180.5	68
1086.5	147	1137	64	1182.5	70
1088.5	270	1140	49	1185.5	89
1090.5	280	1142	45	1189.5	132
1091	134	1146	75	1190.5	240
1093	103	1148	99	1192.5	310
1095.5	120	1149	114	1195.5	270
1098	86	1150	115	1196.5	240
1100	115	1151	123	1198.5	193
1102.5	83	1152.5	111	1202	135
1104	70	1153.5	107	1203	115
1106	91	1155	105	1205	95
1108	132	1157.5	84	1208	123
1109.5	180	1161	56	1210	166
1111.5	490	1163.5	66	1211	182

TABLE 12 (continued)

ABSORPTION COEFFICIENTS OF H₂O $\lambda=850 \text{ \AA}$ to $\lambda=1855 \text{ \AA}$

REF: (a) K. Watanabe, Adv. In Geophys. 5, 199 (1958)

(b) K. Watanabe, *et al.*, AFCRC Tech. Rep. 53-23, Geo. Res. Paper 21, (1953)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
1213	270	1277.5	201	1321.5	165
1215.6	387	1278.5	203	1323.5	149
1218.5	490	1280	210	1325	137
1221	490	1281.5	209	1327	125
1222.5	410	1283	209	1328.5	114
1223.5	320	1284	208	1329.5	116
1226	123	1286	199	1331.5	128
1230	69	1287.5	189	1332.5	128
1234	108	1289	189	1334.5	134
1236	260	1291	192	1336	128
1239	350	1292.5	196	1337	121
1243	260	1294	202	1338.5	114
1244	205	1296	198	1340.5	106
1247.5	153	1298	192	1342.5	99
1249.5	158	1299	185	1344	93
1252.5	163	1300	178	1346	95
1254	175	1301.5	173	1347.5	96
1256	183	1303	171	1349	93
1257.5	185	1305	173	1351	90
1260	183	1306	181	1352	87
1262	183	1308	187	1354	85
1264	194	1309.5	180	1355.5	78
1266	198	1311.5	161	1358	67
1270	209	1313	150	1359	64
1272	201	1314.5	144	1361.5	61
1273.5	197	1315.5	143	1363.5	66
1274.5	193	1318	157	1365.5	64
1275.5	195	1319.5	169	1367	61

TABLE 12 (continued)

ABSORPTION COEFFICIENTS OF H₂O $\lambda=850 \text{ \AA}$ to $\lambda=1855 \text{ \AA}$

- REF: (a) K. Watanabe, Adv. In Geophys. 5, 199 (1958)
 (b) K. Watanabe, et al., AFCRC Tech. Rep. 53-23, Geo. Res. Paper 21, (1953)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
1368	56	1425	13.3	1492	25.2
1369.5	52	1428	13	1495.5	26.4
1371.5	46	1430.5	13.2	1498	27.9
1374.5	47	1433.5	13.2	1500	28.9
1377.5	49	1437	13	1502.5	30.4
1379.5	45	1440	13.2	1505	32
1381	42	1441.5	13.5	1509	34
1383.5	35	1444	13.5	1511.5	35
1386	30	1446.5	13.7	1512.5	36
1388	28	1449	13.6	1515.5	36
1389.5	30	1450.5	13.6	1518	38
1391	31	1452.5	13.4	1521.5	40
1392	33	1455.5	14.3	1523.5	42
1394	32	1458	14.9	1527	44
1395	30	1461	15.5	1529	45
1396.5	29	1464	17	1532.5	47
1399.5	24	1466	17.7	1535	48
1400.5	21	1468	18.1	1538	50
1403	17.8	1470	18.1	1540	52
1406	16.5	1471.5	18.5	1542	53
1407.5	17.4	1474	19.1	1545	55
1409.5	19.4	1476.5	20.1	1548	57
1411	20.2	1478	20.3	1551	59
1413.5	19	1480	20.4	1554	61
1416	17.9	1482	21.1	1557	63
1418.5	16.6	1484	22.4	1559.5	63
1420.5	15.4	1487	23.4	1563	64
1423.5	14.4	1489.5	23.9	1564.5	64

TABLE 12 (continued)

ABSORPTION COEFFICIENTS OF H₂O $\lambda=850 \text{ \AA}$ to $\lambda=1855 \text{ \AA}$

- REF: (a) K. Watanabe, Adv. In Geophys. 5, 199 (1958)
 (b) K. Watanabe, et al., AFCRC Tech. Rep. 53-23, Geo. Res. Paper 21, (1953)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
1566.5	70	1632	115	1730	91
1568	69	1634	117	1735	85
1570	71	1636.5	120	1740	78
1572.5	73	1639	122	1745	74
1575	75	1640	120	1750	70
1578	78	1643	121	1755	68
1580	78	1644.5	123	1760	64
1581.5	79	1647.5	125	1765	58
1584.5	82	1650	124	1770	54
1586	84	1652	123	1775	49
1587	84	1654.5	127	1780	43
1589.5	88	1658	122	1785	39
1591.5	89	1660	122	1790	33
1593.5	90	1663	123	1795	26
1596.5	92	1665	122	1800	21
1599.5	95	1668	121	1805	17
1602.5	98	1672	122	1810	13
1605	99	1675	119	1815	10
1608	103	1680	119	1820	7.7
1612	103	1685	114	1825	5.9
1613	104	1690	114	1830	4.6
1616.5	107	1695	114	1835	3.4
1618.5	108	1700	111	1840	2.6
1621	109	1706.5	110	1845	1.8
1623.5	111	1710	107	1850	1.5
1626	111	1715	106	1855	1.0
1628.5	111	1720	99		
1630.5	113	1725	95		

TABLE 13
 ABSORPTION COEFFICIENTS, k , IN RECIPROCAL CENTIMETERS
 FOR NITROGEN (N_2) AT VARIOUS WAVELENGTHS*

λ A	k						
145	400	221	410	305 8	370	446	450
150	570	224	445	308 5	520	459	420
151	290	230 5	360	309	350	468	435
152	350	231	360	311	430	479	420
155	380	232	360	312 5	280	483	430
156	310	233	530	320	280	504	320
157 5	470	234	440	321	270	505	320
158	420	234 4	550	322	380	507	360
159	470	235 2	440	327	275	508	420
160	530	238 6	470	328	280	5 8 5	440
161	390	240	385	330	285	512	480
163	440	241	620	335	295	513	150
165 5	320	243 3	660	340 5	285	526	440
166	480	244	360	342	310	541	430
168	360	245	480	344	320	554	720
169	320	246	450	346	350	555	480
170	400	249	345	246 5	345	584	400
171	480	251	385	352	340	601	330
172	450	252	340	359	330	602	420
180	250	256	310	361	360	608	480
185	150	258	365	362	380	610	300
186 5	170	259	320	366	380	620	470
188 5	220	260	310	368	375	645	255
189 5	350	264	320	369	360	653	260
191 7	170	266	390	370	390	664	230
192	390	272	290	372	375	685	300
193	350	278	350	373	390	694	420
194 8	330	280	285	377	380	701	345
196	230	284	265	389	400	733	390
197	390	287	265	395	400	740	390
200	350	289	220	398	385	754	440
201	270	290 2	270	401	420	759	360
202	430	291	295	402	400	786	430
203	530	292	255	403	425	770	270
203 5	300	293	265	408	390	776	470
204	340	293	340	411	400	810	560
207	325	294	285	416	390	823	660
209	380	295	270	419 5	390	826	180
210	420	296	520	427	450	827	210
212	380	297	550	429	400	829	150
214	300	298	275	430	510	835 1	200
215	360	299	510	431	500	863	200
216	380	299 5	245	436	445	872	360
217	340	301	340	438	450	876	390
219	450	302	260	440	450	881	270
220 5	440	303 8	275	442	445	929	320

*J Romand, Laboratoires de Bellevue, France, Private Communication (July 1962)

TABLE 14

ABSORPTION COEFFICIENTS OF N₂ $\lambda=303 \text{ \AA}$ to $\lambda=1306 \text{ \AA}$

REF: G.L. Weissler et al. J. Opt. Soc. Am., 42, 84 (1952)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k	λ	k
303.9	110	660.3	690	771.9	1420	971.3	460
374.1	320	671.0	820	772.4	1100	977.0	460
395.6	340	671.4	1030	773.0	950	979.8	720
418.7	360	671.6	800	776.0	2550	989.8	120
418.9	300	671.8	790	787.7	250	991.5	69
507.4	440	672.0	610	790.2	670	1025.7	60
507.8	440	673.8	550	796.7	420	1036.0	310
508.2	440	685.0	730	832.8	92	1036.3	260
515.5	610	685.5	730	833.3	260	1084.0	130
515.6	500	685.8	810	833.7	230	1084.6	130
525.8	490	686.3	860	834.5	140	1085.5	130
537.8	580	702.3	610	835.1	510	1134.2	110
539.5	670	702.8	800	835.3	120	1134.4	93
580.4	710	703.8	720	879.1	440	1135.0	140
584.4	700	718.6	750	903.6	460	1199.5	120
616.3	720	745.8	790	904.0	480	1200.2	160
617.0	760	747.0	840	904.1	490	1200.7	98
635.2	710	748.4	680	904.5	520	1215.1	66
644.2	720	763.3	910	915.96	180	1243.3	65
644.6	720	764.4	640	916.01	360	1302.2	48
644.8	720	765.1	2760	916.7	860	1304.9	100
645.2	720	771.6	2160	971.2	570	1306.0	6.7

TABLE 15

ABSORPTION COEFFICIENTS OF N₂ $\lambda=840 \text{ \AA}$ to $\lambda=990 \text{ \AA}$

REF: K. Watanabe, Hawaii Inst. of Geophys. Contr. No. 29, Dec. 1961.

Selected Points

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
840.6	1309.6	894.1	70.0	930.8	64.0
841.9	1021.0	901.6	130.0	931.4	10.1
843.6	18.6	903.8	30.0	937.8	370.0
845.3	1031.0	905.4	30.0	948.8	170.0
846.1	41.0	909.2	90.0	955.5	90
849.7	723.8	910.3	150.0	960.5	1600
852.8	40.5	911.3	640.0	966.0	1600
855.6	580.0	914.1	35.0	972.6	10000.0
859.0	170.0	916.0	35.0	980.5	1100
863.4	19.3	916.8	350.0	982.1	10.9
868.8	80.0	919.1	4.0	984.3	0.6
880.6	700.0	920.0	280.0	985.6	240
886.1	540.0	923.9	400.0		
890.7	100.0	926.2	260.0		

TABLE 16

ABSORPTION COEFFICIENTS OF A

 $\lambda=602 \text{ \AA}$ to $\lambda=844 \text{ \AA}$ REF: P Lee and G.L. Weissler, Phys. Rev., 99, 540 (1955)

k in Reciprocal Centimeters

λ	k	λ	k
602.8	850	745.8	940
617.1	850	747.0	940
625.8	860	769.1	890
637.2	900	771.9	970
644.1	900	772.3	920
660.3	900	776.0	960
671.7	940	779.8	515
683.2	940	781.2	520
700.3	950	827.3	0
725.5	880	843.7	0

TABLE 17

ABSORPTION COEFFICIENTS, k , IN RECIPROCAL CENTIMETERS
FOR NITRIC OXIDE (NO) AT VARIOUS WAVELENGTHS*

λ A	k	λ A	k	λ A	k	λ A	k
168	430	251	600	352	530	630	360
169	460	252	720	353	690	637	780
172	800	253	710	358	680	644	360
173	920	259	670	361	810	651	640
175	540	205	760	364	630	693	740
177	640	278	540	367	610	701	680
178	820	280	640	369	590	715	300
180	500	283 7	680	370	660	730	800
185	680	284 5	520	377	570	733	720
188 5	560	286	620	389	590	790	760
191 7	520	287	740	390	540	810	620
192	750	289	700	393	580	833	440
192 2	420	290	520	395	640	834	560
193	620	293	640	398	660	865	620
194 8	340	294	660	402	630	870	380
196	710	295	480	408	670	892	580
197	600	297	600	411	660	898	640
199	340	299	420	419 5	630	912	540
200	680	302	620	425	620	935	420
202	360	305 8	430	434	620	975	620
207	520	308 5	380	453	580		
209	330	309	460	454	630		
212	560	311	350	461	670		
217	650	315	520	476	610		
219	550	320	560	480	640		
221	390	321	430	502	600		
225	600	322	540	504	620		
230 5	840	325	510	508	740		
232	680	328 5	550	512	800		
234	520	330	530	527	800		
235 2	640	333	650	538	1000		
236 5	800	337	620	555	660		
240	780	338	850	567	540		
240 5	720	340	570	570	660		
244	540	344	710	601	390		
246	600	347	650	602	620		
248	800	350	690	629	560		

*J. Romand, Laboratoires de Bellevue, France, Private Communication
(July 1962)

TABLE 18

ABSORPTION COEFFICIENTS OF NO

 $\lambda=374 \text{ \AA}$ to $\lambda=1306 \text{ \AA}$ REF: H. Sun, G.L. Weissler; J. Chem. Phys. 23, 1372 (1955)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
374.1	340	747.0	260	923.2	600
374.3	390	763.3	300	923.7	630
537.8	580	764.4	1020	924.3	640
538.3	500	765.1	200	955.3	430
539.1	600	771.5	350	977.0	560
539.5	530	771.9	250	979.9	350
539.8	560	772.4	300	1006.0	300
600.0	540	773.0	310	1037.0	220
644.1	530	776.0	400	1037.3	220
644.6	600	796.7	390	1134.4	100
644.8	570	832.9	280	1135.0	84
645.2	550	833.3	450	1199.5	74
660.3	450	833.7	280	1200.2	82
671.4	470	834.5	370	1200.7	74
672.9	570	835.3	370	1243.3	82
673.8	590	911.9	670	1276.1	56
702.3	390	916.0	650	1276.2	81
702.9	390	916.7	670	1302.2	130
703.8	390	922.5	540	1304.9	110
745.8	400	923.0	560	1306.0	100

TABLE 19

ABSORPTION COEFFICIENTS OF NO

 $\lambda=1065 \text{ \AA}$ to $\lambda=1345 \text{ \AA}$ REF: K. Watanabe, Adv. in Geophys. 5, 193-94 (1958)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
1065.0	250	1166.0	69	1260.3	56
1066.0	231	1169.1	68	1261.8	54
1080.2	204	1172.1	72	1264.2	50
1081.7	239	1174.3	70	1266.4	54
1084.7	175	1175.8	69	1268.6	58
1087.1	210	1178.2	65	1270.6	57
1088.7	161	1180.4	61	1274.0	65
1090.0	151	1182.5	61	1277.1	51
1092.7	129	1184.7	60	1278.0	49
1095.3	126	1187.8	63	1279.5	47
1097.9	121	1189.3	63	1281.1	53
1100.5	116	1191.5	63	1283.1	60
1102.1	110	1193.2	62	1284.3	76
1104.3	110	1195.6	62	1286.4	75
1105.8	116	1198.0	60	1287.5	72
1107.1	151	1200.3	62	1290.4	48
1111.0	180	1202.1	59	1293.3	54
1112.0	161	1204.9	58	1295.3	63
1114.9	126	1206.6	59	1297.2	61
1116.3	121	1209.2	57	1299.7	52
1119.0	99	1211.3	58	1302.3	46
1121.2	110	1215.6	65	1304.1	58
1124.0	99	1217.4	65	1307.2	52
1126.3	99	1219.2	64	1310.9	59
1127.5	116	1220.9	62	1312.8	57
1131.4	81	1223.4	59	1315.4	47
1133.2	81	1225.5	55	1316.8	49
1135.3	86	1228.2	51	1319.0	53
1137.5	94	1230.0	53	1323.3	84
1139.7	91	1231.9	56	1325.1	87
1141.5	94	1233.8	55	1327.6	88
1144.2	91	1235.4	54	1329.3	48
1145.9	86	1239.5	54	1333.9	78
1146.9	86	1241.3	56	1335.9	93
1148.5	80	1243.2	54	1338.6	59
1150.8	80	1245.9	53	1341.3	43
1154.0	75	1247.4	54	1342.3	41
1157.0	75	1251.3	65	1343.7	43
1159.7	75	1253.6	51	1345.5	51
1161.2	70	1255.0	52		
1163.7	69	1257.2	57		

TABLE 20

 ABSORPTION COEFFICIENTS, k , IN RECIPROCAL CENTIMETERS
 FOR NITROUS OXIDE (N_2O) AT VARIOUS WAVELENGTHS*

λ A	k	λ A	k	λ A	k	λ A	k
163	200	240	770	370	930	965	670
164	250	240 5	740	372	810	981	610
165	220	243 3	990	373	1240		
166	430	246	840	377	960		
168	510	247	890	389	1070		
169	450	248	660	395	1180		
170	530	253	600	401	820		
171	430	262	330	402	1050		
172	370	263 8	340	403	1120		
173	520	265	470	408	1060		
177 8	600	273	690	411	1140		
180	620	277	810	416	1100		
182	600	280	820	419 5	720		
186 5	560	284 5	680	427	1000		
188 5	600	289	800	446	830		
189 5	680	290	1000	468	740		
191 7	660	293	1020	505	720		
192 2	710	296	1050	508 5	510		
193	620	300	1080	513	450		
194 8	660	307	1000	526	480		
195 5	630	308	780	527	1020		
196	730	309	1020	532	830		
197	750	310	870	538	550		
200	720	312	1100	547	700		
201	660	320	760	553	830		
202	670	321	930	555	800		
203	720	324	1000	570	720		
204	700	325	780	602	1040		
205	720	328	880	629	870		
207	800	330	760	636	730		
212	760	333	1240	652	840		
214	820	335	900	692	1080		
215	740	340 5	820	707	840		
222	780	342	900	720	820		
230.5	820	344	1120	759	1000		
231	920	346	870	788	>>		
232	820	346 5	795	810	1130		
233	860	352	1110	871	1180		
235	780	359	870	890	1040		
236.5	840	361	930	901	790		
238.6	900	366	1120	912	1100		

*J. Romand, Laboratoires de Bellevue, France, Private Communication (July 1962).

TABLE 21

ABSORPTION COEFFICIENTS OF N_2O $\lambda=1080 \text{ \AA}$ to $\lambda=2160 \text{ \AA}$ REF: K. Watanabe *et al.*, AFCRC Tech. Rep. No. 53-23, Geophys.
Res. Paper No. 21, December (1953)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
1082	880	1172	1950	1265	1610
1087	1150	1175	2050	1269	1810
1089.5	1370	1177.5	2490	1271	1950
1091.5	1200	1179	2320	1273	2050
1093.5	850	1180	770	1274	2160
1095.5	690	1182	400	1275	2100
1097	920	1185	280	1276.5	2320
1098	1350	1189	126	1278	2280
1100.5	1450	1190	112	1279.5	2330
1104.5	1270	1192	104	1282	2430
1107	1270	1196	84	1283	2470
1109	1020	1198	83	1285.5	2430
1112	750	1201	72	1287	2370
1115.5	680	1202.5	67	1288	2330
1118	900	1205	65	1290	2390
1120	790	1209	74	1292	2590
1122	560	1211	70	1293	2260
1124	490	1215.6	66	1297	2190
1126.5	590	1218	68	1299.5	2060
1130	930	1222	84	1302	1920
1132	740	1223	87	1307	1670
1135.5	490	1225.5	112	1311	1490
1141	620	1229.5	133	1312	1340
1145	600	1234.5	188	1315	1160
1148	520	1239	272	1317	1080
1151	610	1242.5	390	1319	920
1152.5	730	1246.5	520	1323	850
1153.5	810	1249	610	1327	630
1155.5	930	1251.5	730	1331	560
1157	1000	1253	810	1332	520
1161	1330	1255	930	1335.5	410
1162	1450	1256.5	1000	1337	350
1163	1470	1261	1330	1338	330
1166	1610	1263	1450	1340	300
1168.5	1810	1264	1470	1342	260

TABLE 21 (continued)

ABSORPTION COEFFICIENTS OF N₂O $\lambda=1080 \text{ \AA}$ to $\lambda=2160 \text{ \AA}$ REF: K. Watanabe *et al.*, AFCRC Tech. Rep. No. 53-23, Geophys.
Res. Paper No. 21, December (1953)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
1343.5	220	1433	152	1512	26
1345	198	1434	162	1515	25
1347	175	1436	156	1516	27
1350	130	1439.5	145	1518	25
1353	103	1441	141	1521	15.7
1354.5	88	1443.5	209	1523	11.8
1357	74	1446	205	1525	10.3
1361	53	1448	152	1526	11.1
1363	47	1450.5	147	1528.5	13.4
1367	32	1452	177	1532	10.6
1370.5	27.1	1455	242	1534	9.7
1374	22.3	1458	169	1535	8.5
1376	21.2	1460.5	137	1536	7.6
1380	19.5	1463.5	153	1537.5	5.9
1382.5	18.7	1466	224	1539	5.3
1385.5	19	1468	148	1539.5	4.8
1387	19.5	1470	115	1540	4.6
1390.5	20.5	1474	124	1541.5	4.6
1394	21.3	1476.5	164	1543	5.6
1396	24.5	1480	102	1545	7
1398.5	28	1481	87	1546	6.2
1402	30	1484	72	1547	5.1
1405	39	1486.5	81	1549	4.2
1407	44	1488	99	1550.5	3.4
1410	47	1489	101	1552	3.3
1413	56	1491	84	1553.5	2.6
1416	76	1492	72	1557	2.2
1418	72	1493	62	1559	2.1
1420	75	1496	47	1563	3.4
1422	85	1499.5	42	1564	2.9
1423	98	1501	58	1567.5	1.60
1424.5	108	1502	60	1568.5	1.38
1428	114	1504.5	39	1570	1.32
1430	107	1508.5	25	1572	1.27
1431.5	124	1511	23	1574	1.11

TABLE 21 (continued)

ABSORPTION COEFFICIENTS OF N₂O $\lambda=1080 \text{ \AA}$ to $\lambda=2160 \text{ \AA}$ REF: K. Watanabe *et al.*, AFCRC Tech. Rep. No. 53-23, Geophys.
Res. Paper No. 21, December (1953)

k in Reciprocal Centimeters

λ	k	λ	k	λ	k
1574.5	1.14	1639	1.26	1867	3.56
1575.5	1.07	1640	1.35	1877	3.43
1577.5	1.09	1644	1.42	1887	3.27
1579.5	1.48	1647	1.51	1897	3.15
1581	1.64	1649.5	1.51	1907	2.89
1583	1.37	1651.5	1.60	1917	2.75
1584	1.26	1652.5	1.66	1927	2.59
1585.5	1.08	1654	1.59	1937	2.33
1587	0.95	1656.5	1.66	1940	2.21
1589	0.88	1657.5	1.59	1947	2.16
1590	0.88	1660	1.63	1950	2.00
1591.5	0.88	1662.5	1.75	1957	1.89
1593	0.90	1664.5	1.84	1960	1.79
1593.5	0.96	1667	1.87	1967	1.84
1594.5	0.82	1669	1.81	1970	1.61
1596	0.89	1671	1.89	1977	1.61
1598	1.03	1673.5	1.84	1980	1.42
1599	1.11	1674.5	1.86	1990	1.27
1600	1.11	1677	1.98	2000	1.10
1602	1.10	1687	2.15	2010	0.96
1604.5	0.99	1697	2.31	2020	0.84
1608	1.01	1707	2.46	2030	0.70
1612	1.06	1717	2.65	2040	0.59
1613	1.06	1727	2.91	2050	0.50
1615.5	1.03	1737	3.00	2060	0.42
1616.5	1.05	1747	3.08	2070	0.35
1618	1.05	1757	3.34	2080	0.29
1621	1.03	1767	3.46	2090	0.24
1623.5	1.25	1777	3.52	2100	0.19
1625	1.25	1787	3.75	2110	0.15
1626	1.29	1797	3.72	2120	0.12
1628.5	1.19	1807	3.77	2130	0.11
1630.5	1.27	1817	3.83	2140	0.09
1634	1.30	1827	3.80	2150	0.07
1635.5	1.41	1837	3.83	2160	0.05
1636	1.28	1847	3.70		
1637	1.41	1857	3.59		

TABLE 22

ABSORPTION COEFFICIENTS OF NH₃ $\lambda=374 \text{ \AA}$ to $\lambda=1306 \text{ \AA}$ REF: H. Sun and G.L. Weissler, J. Chem. Phys. 23, 1160 (1955)

k in Reciprocal Centimeters

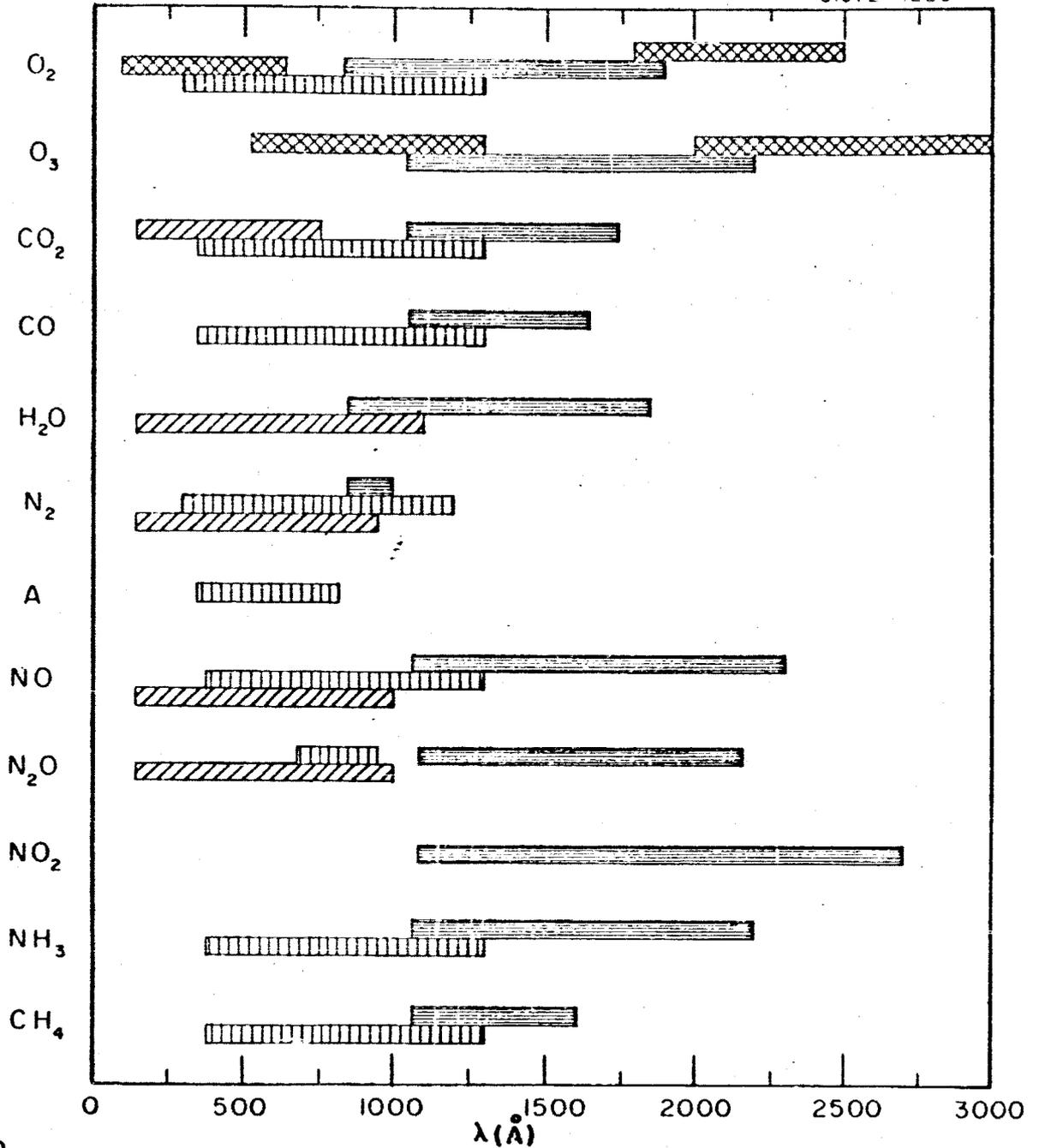
λ	k	λ	k	λ	k
374.1	538	685.5	833	883.2	860
374.3	457	685.8	833	887.4	941
503.7	780	686.3	780	915.9	564
511.5	645	702.3	887	916.0	538
538.3	753	702.9	941	916.7	564
539.2	753	703.9	941	922.5	618
539.4	699	718.5	914	923.0	618
539.9	833	723.4	914	923.2	618
555.1	726	725.5	860	923.5	699
580.4	753	730.9	914	924.3	645
581.0	780	740.2	941	977.0	645
582.2	780	746.8	833	979.8	672
599.6	726	747.0	887	988.8	618
604.2	833	763.3	968	989.8	511
616.3	860	764.5	968	991.5	538
617.1	833	765.1	887	1036.0	511
635.2	941	771.5	887	1037.0	538
637.3	914	771.9	887	1084.0	511
641.4	726	772.4	914	1084.6	538
641.8	833	773.0	914	1134.4	591
643.3	753	776.0	887	1135.0	618
644.1	833	796.7	887	1183.0	484
644.6	833	832.8	860	1184.5	457
644.8	806	833.3	833	1199.5	210
645.2	753	833.7	860	1200.2	210
660.3	753	835.1	806	1200.7	210
661.9	806	835.3	860	1243.3	97
664.6	806	840.0	941	1275.1	151
666.0	860	843.8	914	1276.2	121
670.9	833	850.6	941	1302.2	403
671.9	833	871.1	806	1304.9	220
672.0	860	875.5	780	1306.0	726
673.0	860	878.7	699		
685.0	887	879.6	726		

TABLE 23

ABSORPTION COEFFICIENTS OF CH₄ $\lambda=374 \text{ \AA}$ to $\lambda=1306 \text{ \AA}$ REF: H. Sun and G.L. Weissler, J. Chem. Phys. 23, 1160 (1955)

k in Reciprocal Centimeters

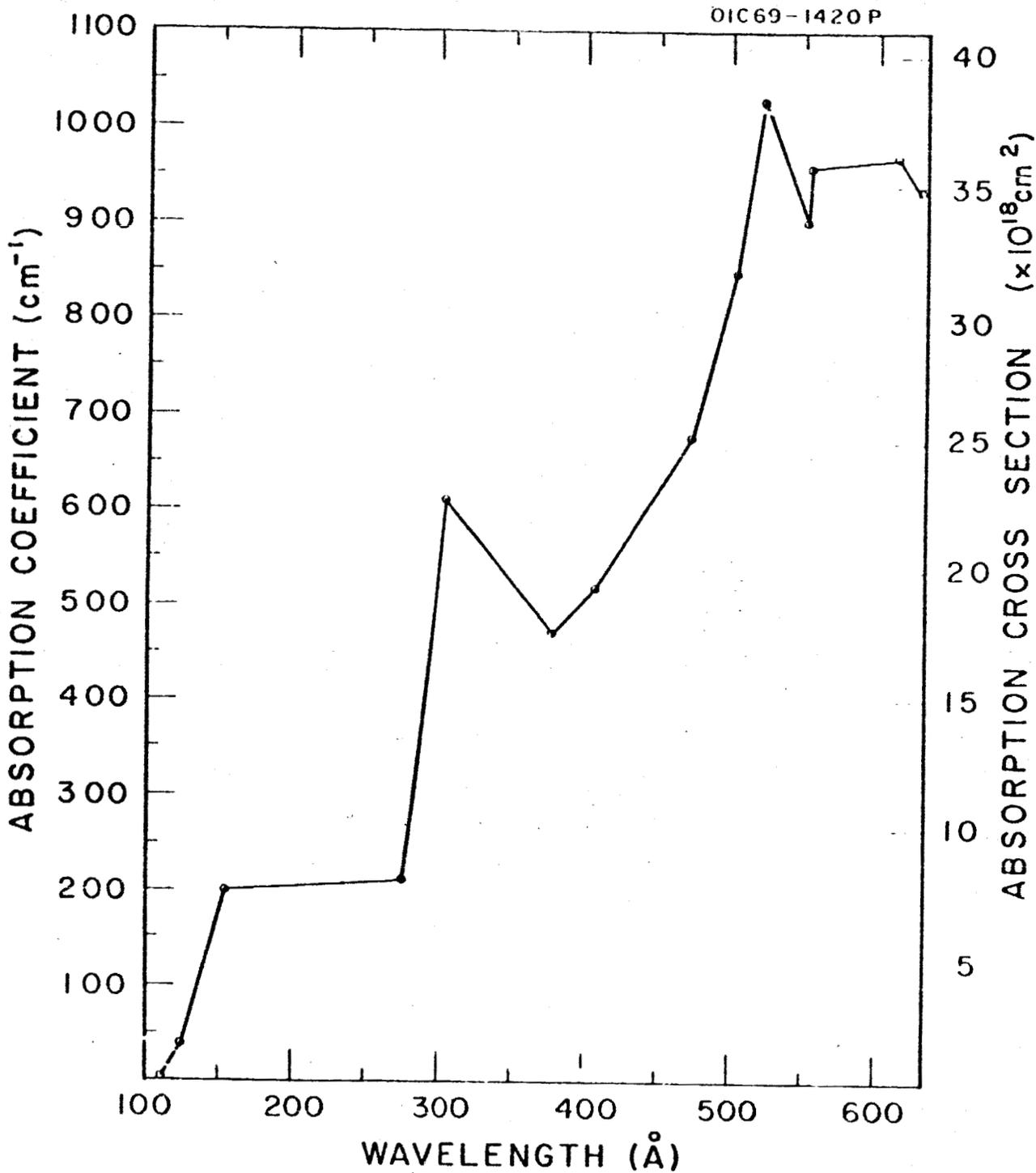
λ	k	λ	k	λ	k
374.3	376	772.4	1022	977.0	1183
507.7	672	772.9	1156	979.8	1102
508.2	618	775.9	1048	989.8	1022
537.8	645	776.7	1129	991.5	780
538.3	618	796.7	1129	1036.3	833
580.4	672	833.3	1156	1037.0	833
581.0	672	833.7	1236	1065.9	833
582.2	672	834.6	1290	1071.8	860
599.6	833	835.1	1129	1084.6	726
600.6	833	840.0	1102	1085.5	780
616.3	833	850.6	1156	1134.4	511
617.1	914	851.6	1183	1135.0	511
629.2	968	864.7	1129	1152.1	511
629.4	941	871.1	1129	1175.5	618
644.1	968	875.8	1209	1176.4	672
644.6	726	879.6	1102	1183.0	618
644.8	860	883.2	1048	1184.5	538
645.2	780	887.4	1022	1199.5	511
660.3	887	916.0	1236	1200.2	538
685.0	860	916.7	1317	1200.7	511
686.3	968	923.2	1236	1206.9	484
745.8	1048	924.3	1129	1215.7	430
747.0	941	932.0	1290	1217.6	511
763.3	968	951.9	1505	1243.3	484
764.5	968	954.8	1505	1275.1	430
765.1	1075	955.5	1505	1302.2	376
771.5	1048	958.5	1613	1304.9	376
771.9	1156	961.5	1505	1306.0	376



LEGEND

WATANABE et al.		ROMAND	
WEISSLER et al.		OTHER	

**SUMMARY OF ABSORPTION CROSS SECTION STUDIES
BY REGION**
Figure 1

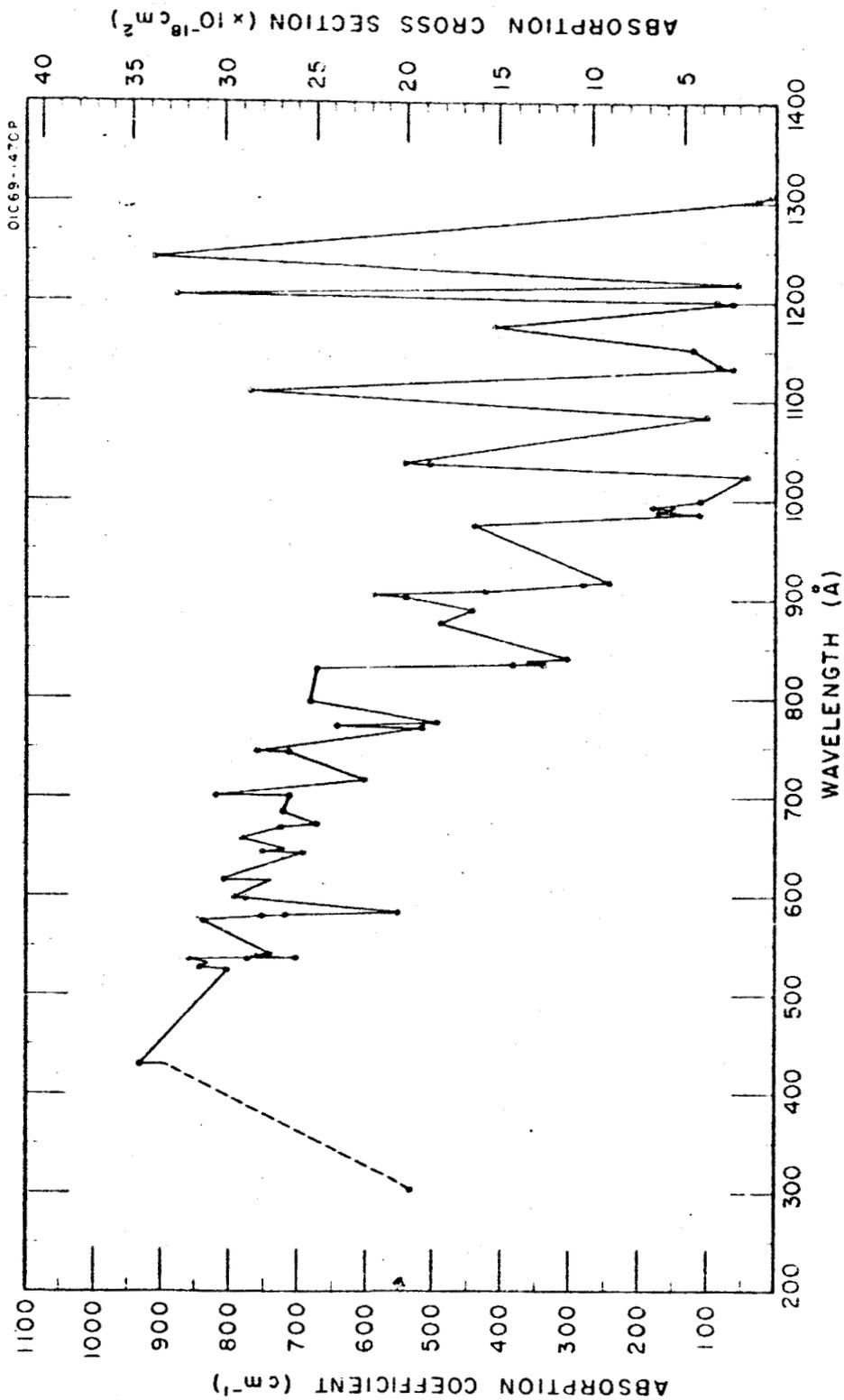


ABSORPTION COEFFICIENTS & CROSS
SECTIONS OF O₂ 100-650 Å

REF.: A.A. ABOUD et al, J. OPT. SOC. AM. 45, 767 (1955)

ACCURACY ± x11 TO ± x2

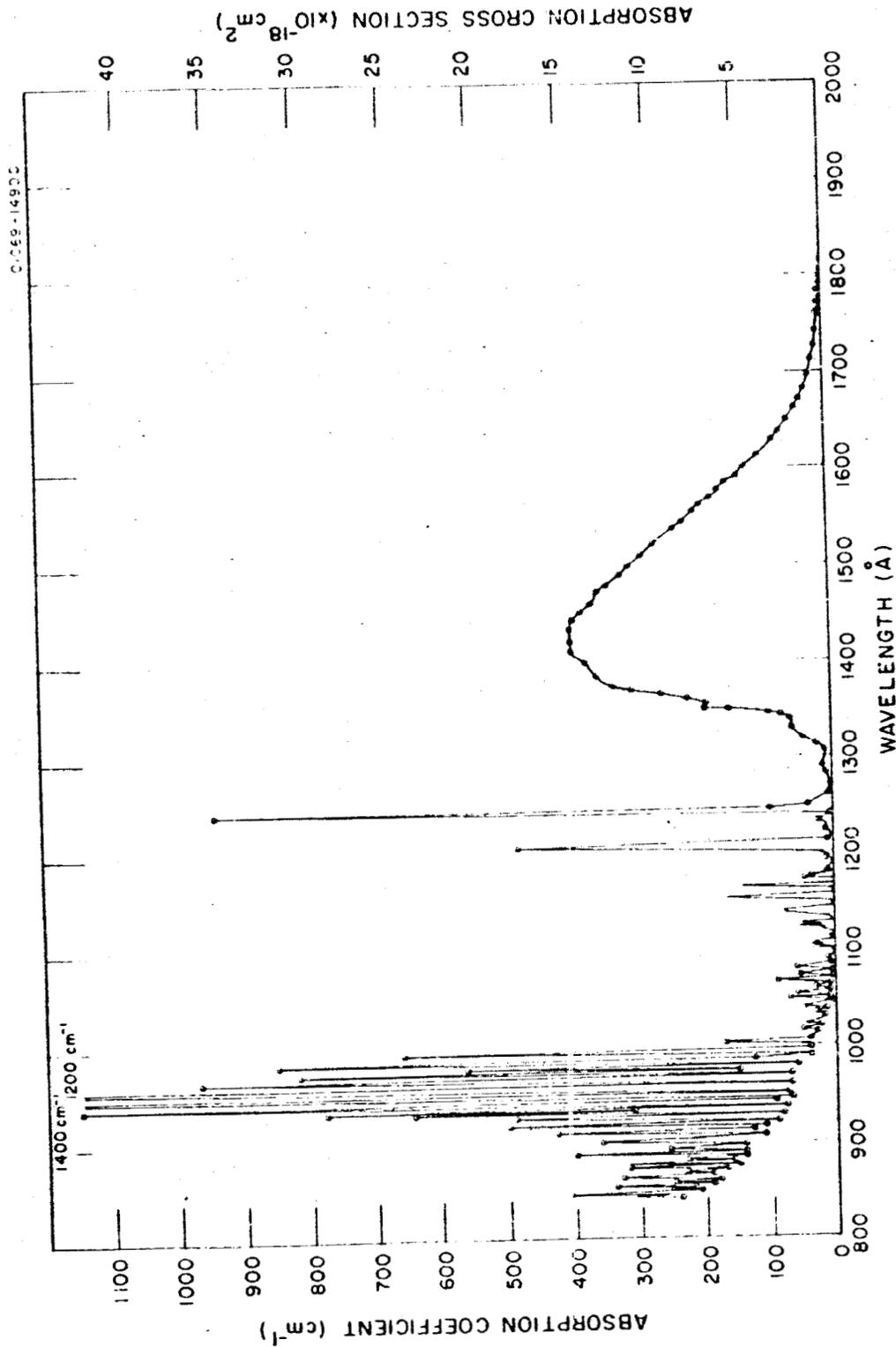
Figure 2



ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF O₂
300 - 1300 Å

REF: G.L. WEISSLER AND P. LEE, J. OPT. SOC. AM. 42, 200 (1952)
 ACCURACY: ± 10% K > 100, ± 15% K ≤ 100

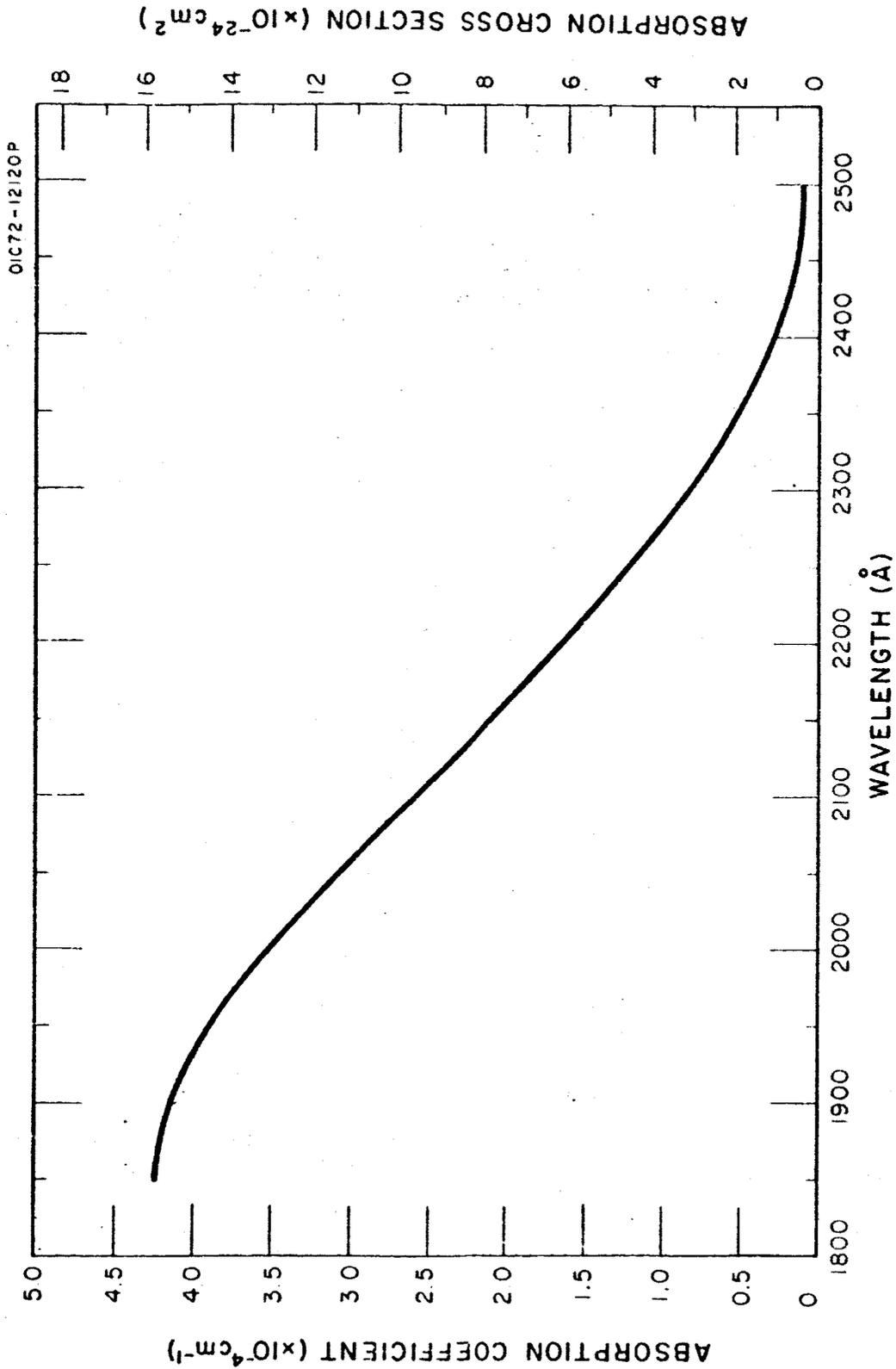
Figure 3



**ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF O₂
840-1800 Å**

REF: K. WATANABE *et al.* (SEE TABULATION)
ACCURACY: SEMI-QUANTITATIVE TO $\pm 15\%$

Figure 4



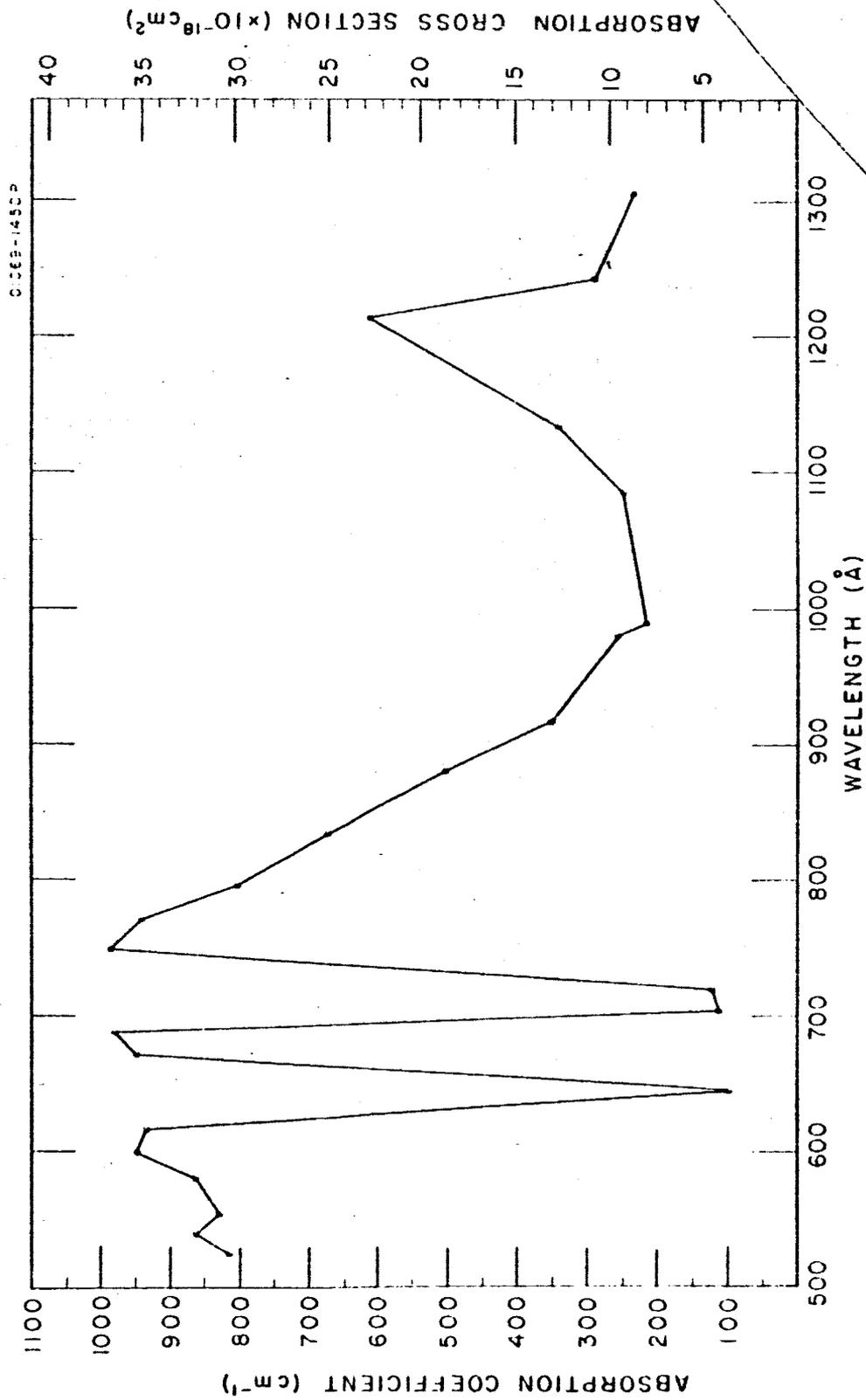
ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF O₂ 1850Å - 2500Å

REF: R.W. DITCHBURN, P.A. YOUNG, J. ATM. TERR. PHYS. 24, 127 (1962)

EXP. ERROR: 1850 - 2000Å, ±20%; 2000 - 2500Å, ±1.0 × 10⁻²⁴ cm²

VALUES INCLUDE THE EFFECT OF RAYLEIGH SCATTERING

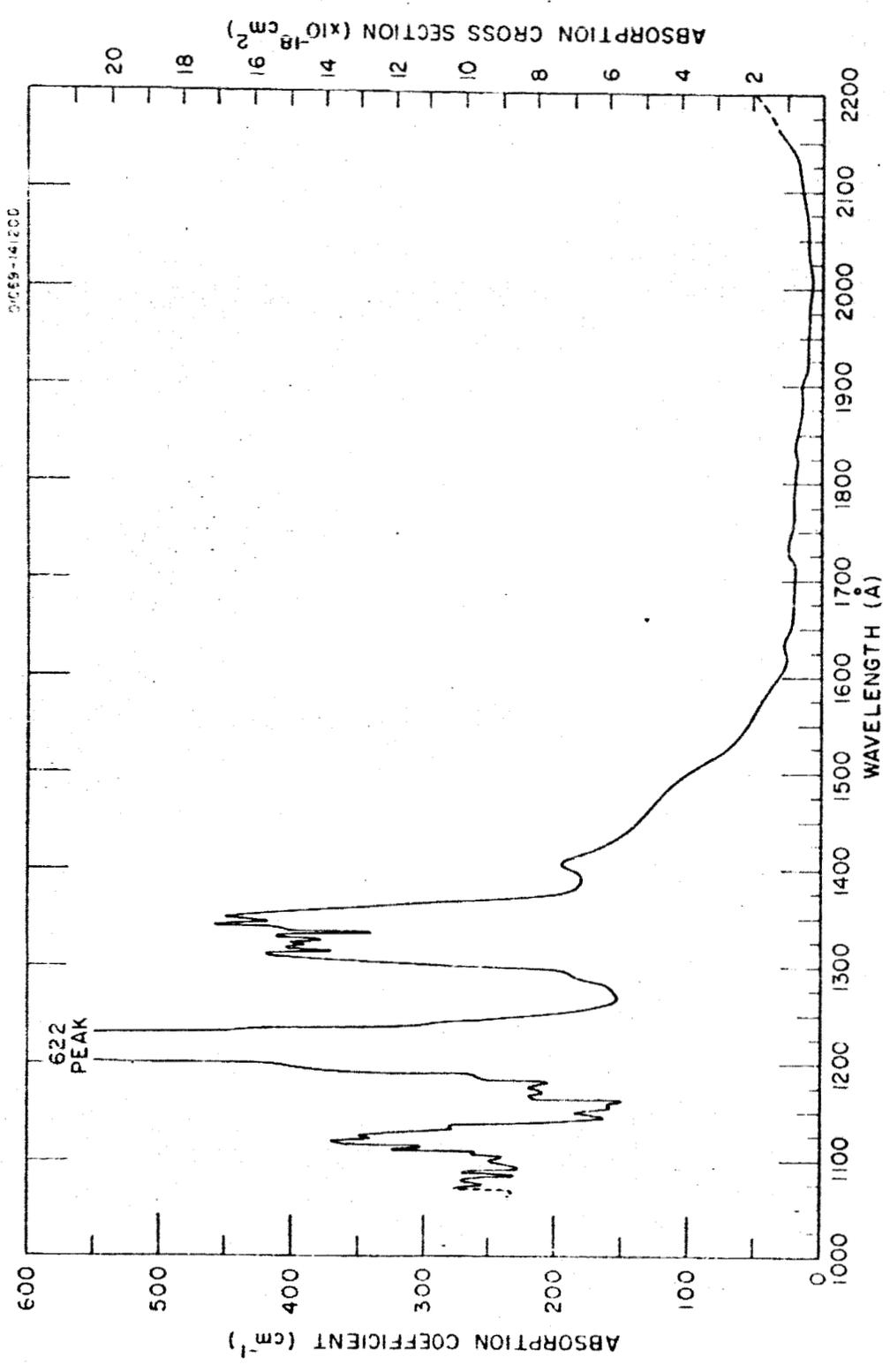
Figure 5



**ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF O₃
525 - 1300 Å**

REF. : M. OGAWA, G.R. COOK, J. CHEM. PHYS. 28, 173 (1958)
ACCURACY: < ± 20%

Figure 6

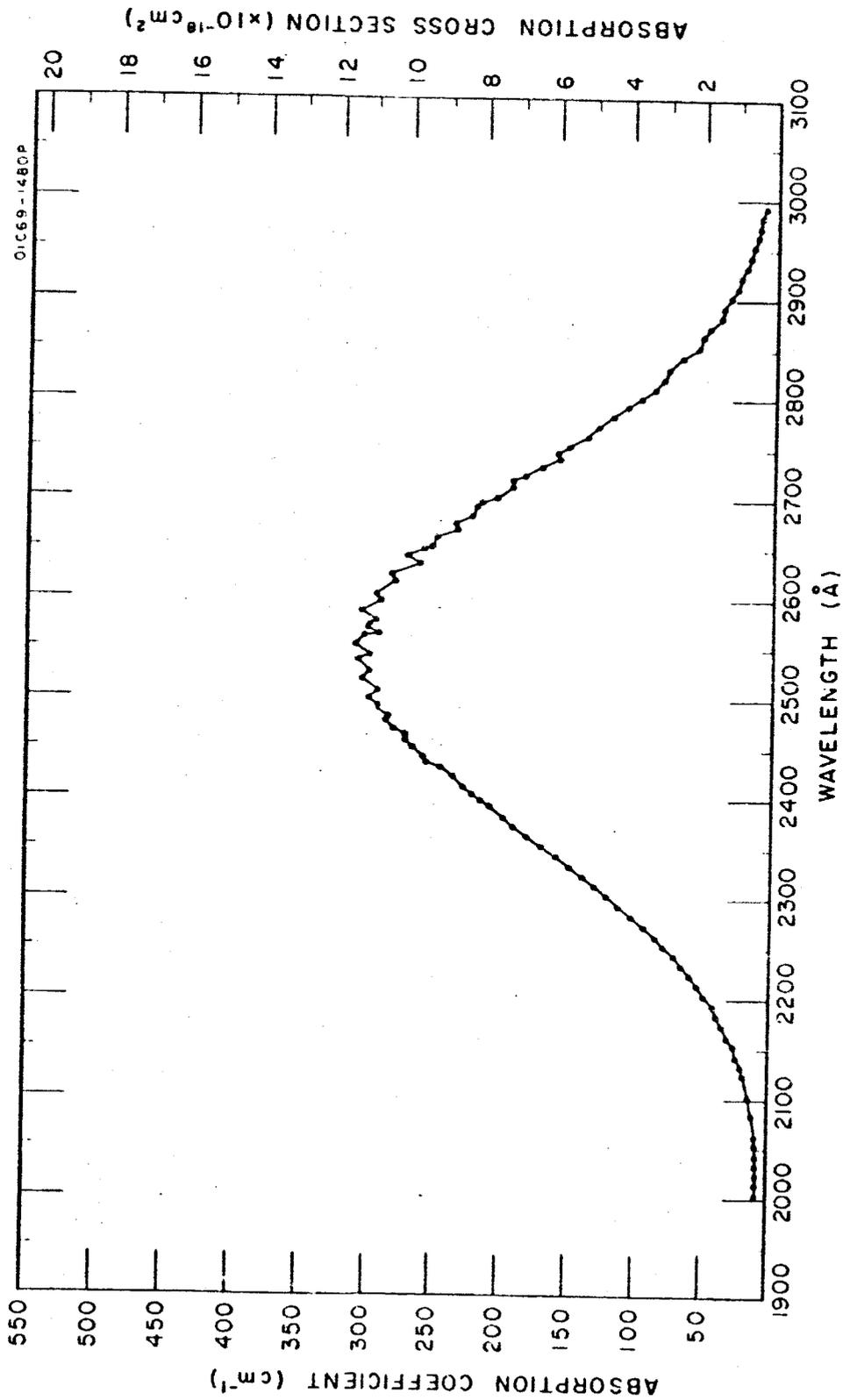


ABSORPTION COEFFICIENTS AND CROSS-SECTIONS OF O₃
 1050-2200 Å

REF: 1050-1350 Å, 1350-2200 Å, CURVES, K. WATANABE, *et al.*, AFCRC
 TECH. REP. NO. 53-23, GEO. RES. PAPER NO. 21, JUN. 1953

ACCURACY: ±10%

Figure 7

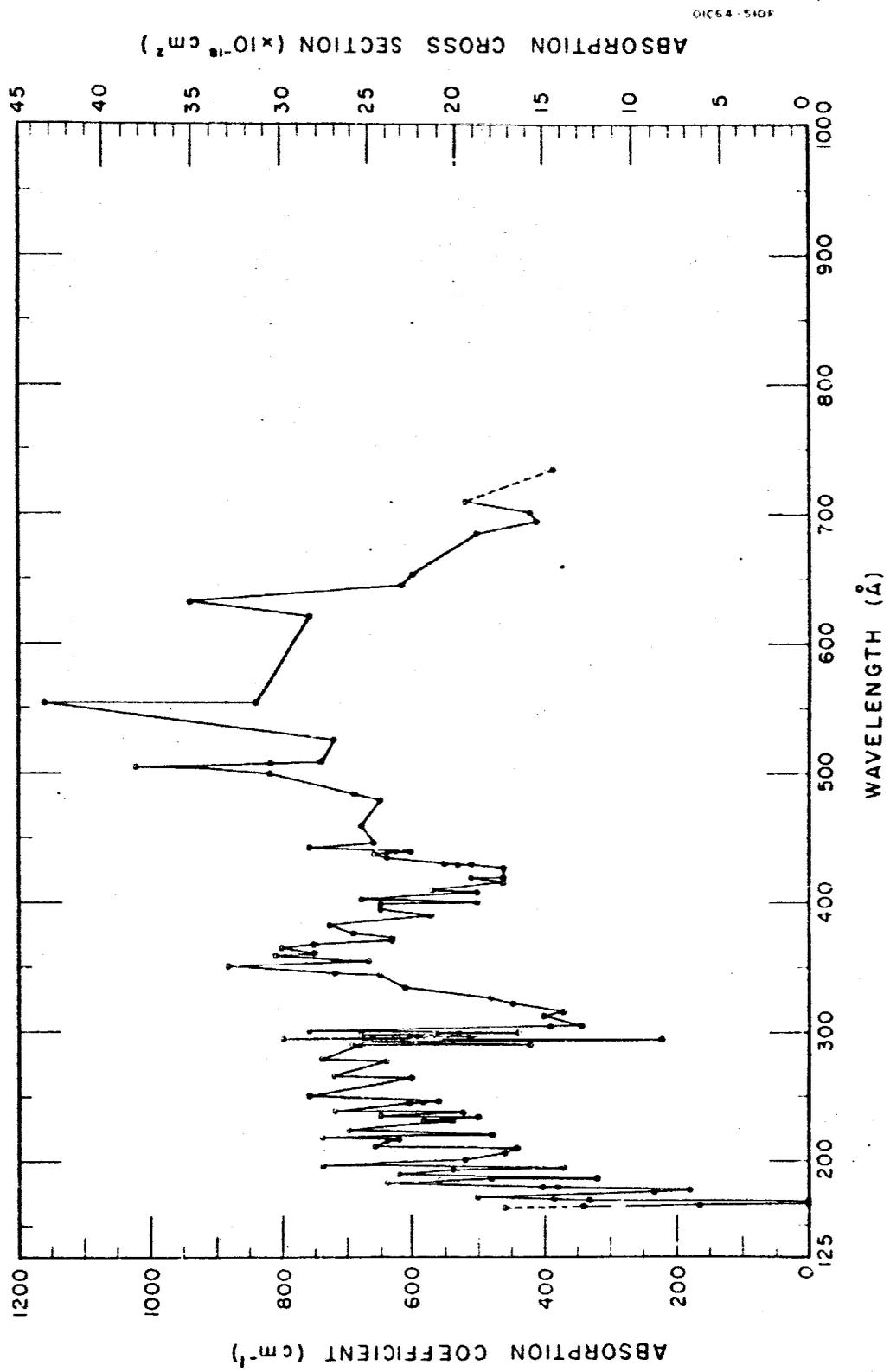


ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF O₃
2000 - 3000 Å

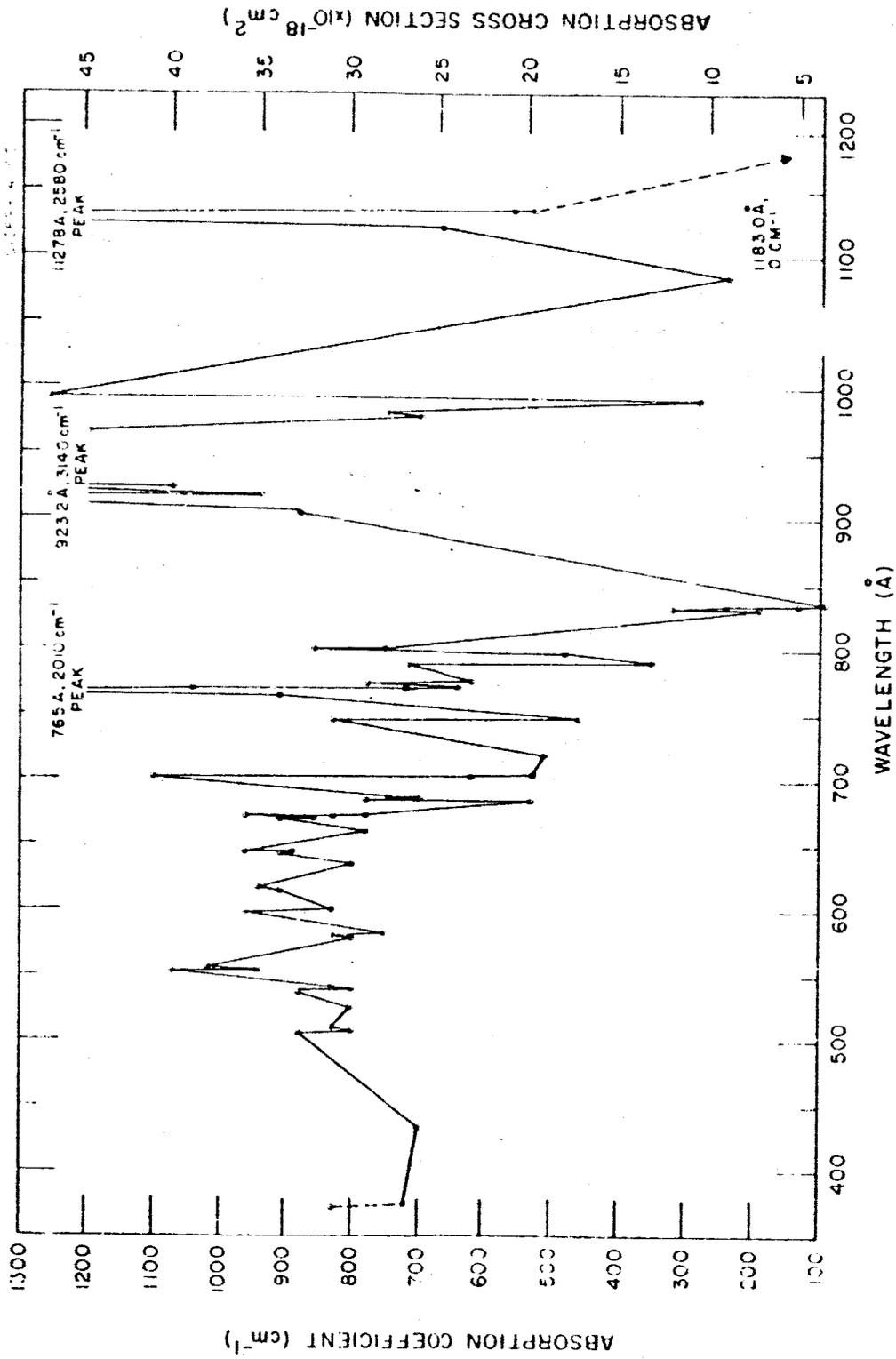
REF: E.C.Y. INN, Y. TANAKA, "OZONE ABSORPTION COEFFICIENTS,"
ADVANCES IN CHEMISTRY SERIES NO. 21, 1959

ACCURACY: ± 5 %

Figure 8



01664-510P

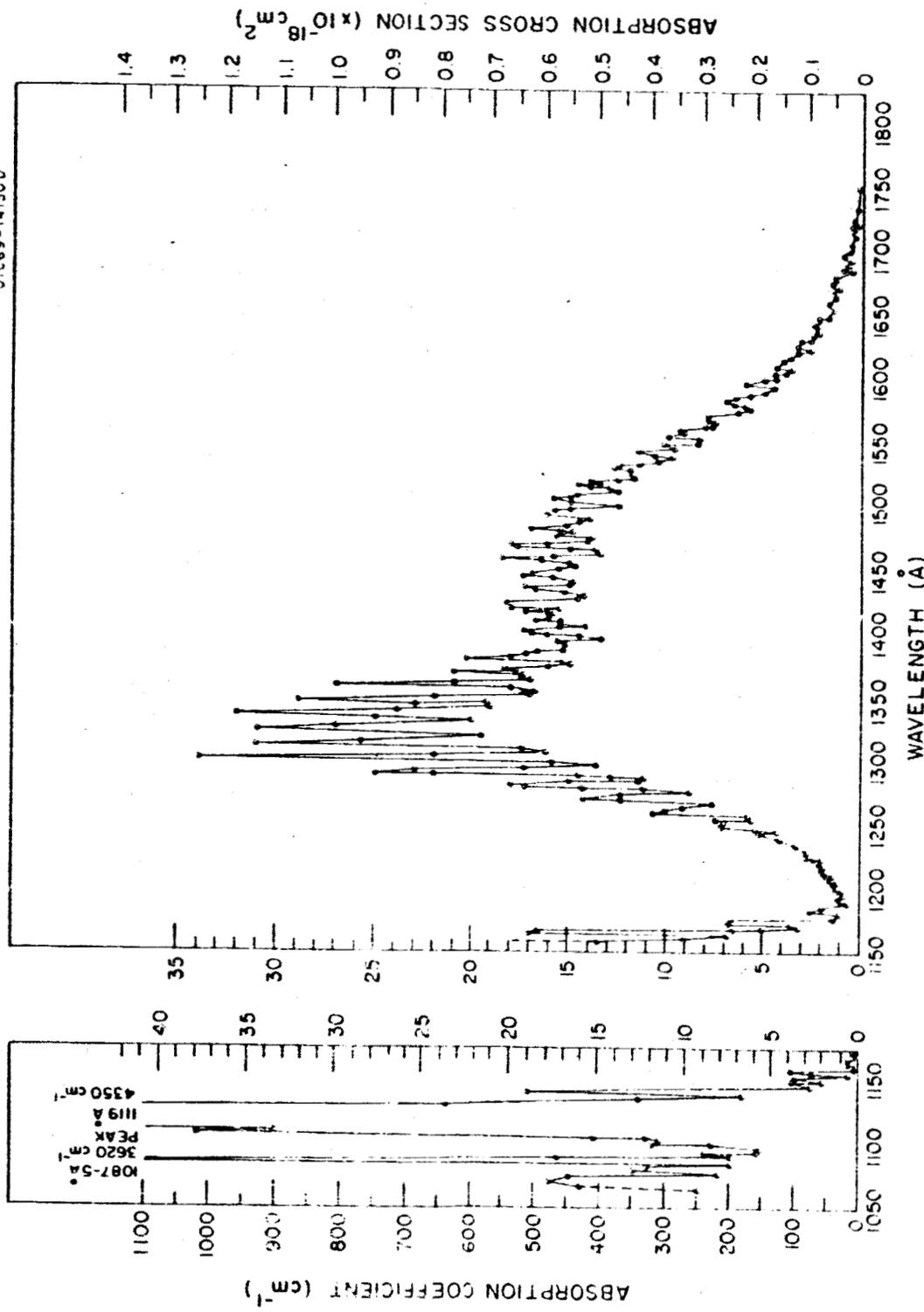


ABSORPTION COEFFICIENTS AND CROSS-SECTIONS OF CO₂
375-1185 Å

REF. H. SUN AND G.L. WEISSLER; J. CHEM. PHYS., 23, 1625 (1955)
ACCURACY: 10-15%, WITH EXCEPTIONS

Figure 10

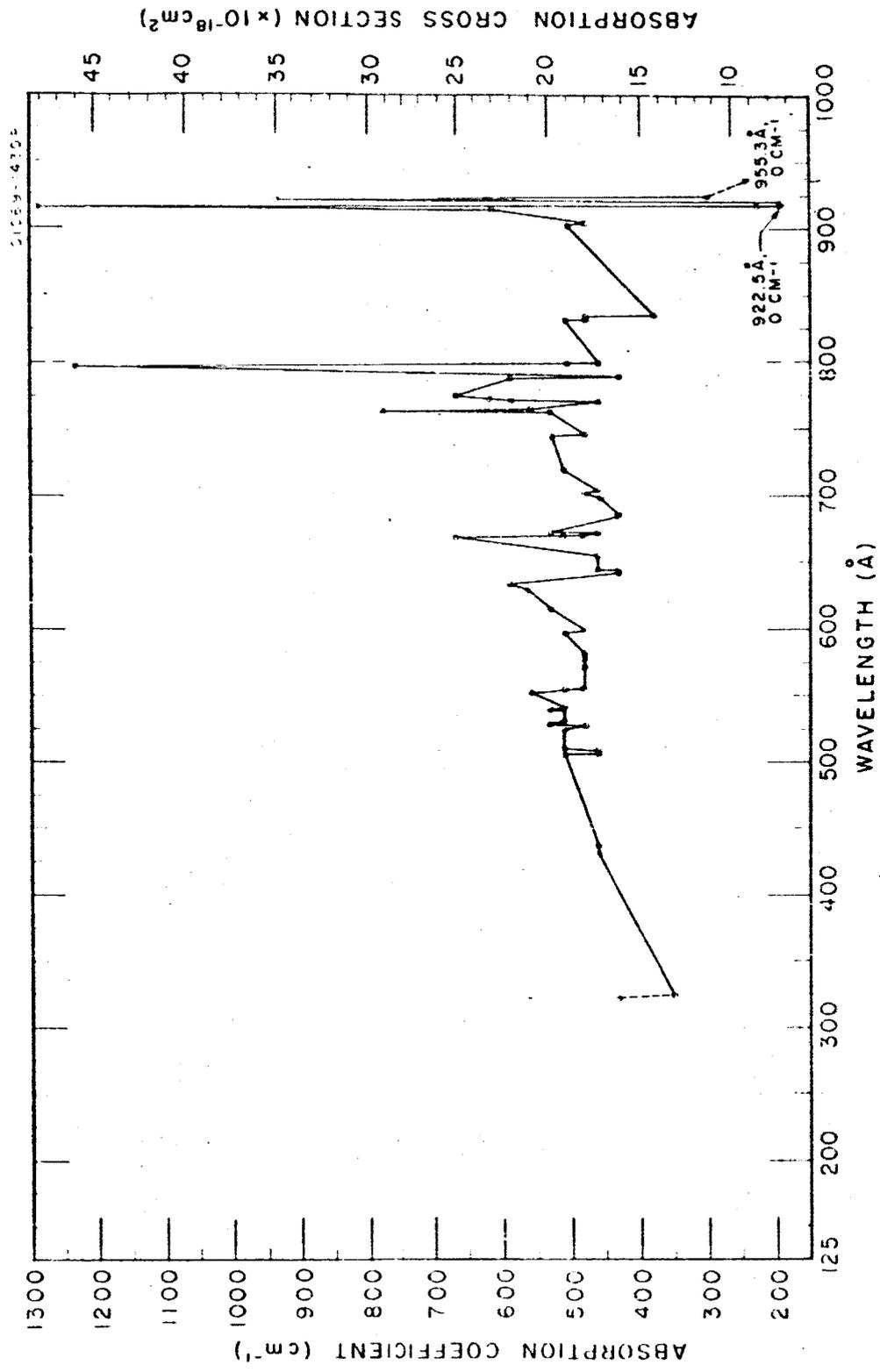
01669-141300



ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF CO₂ 1050-1750 Å

REF: K. WATANABE, *et al.*, AFCRC TECH. REP. NO. 53-23,
GEO. RES. PAPER NO. 21, JUN. 1953

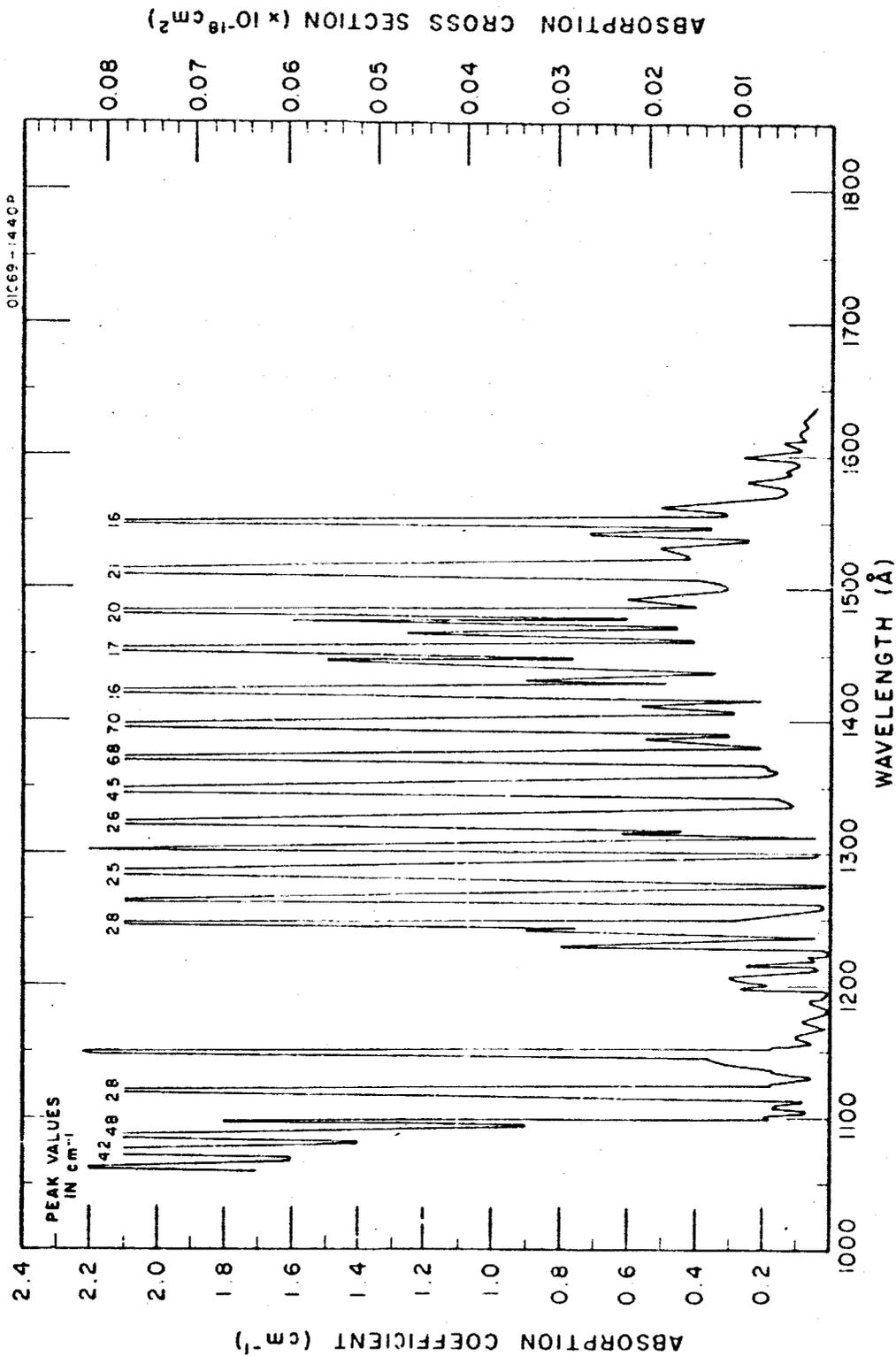
Figure 11



ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF CO
325 - 950 Å

REF: H.SUN AND G.L.WEISSLER; J. CHEM. PHYS., 23, 1625 (1955)
ACCURACY: 10 - 15 %, WITH EXCEPTIONS

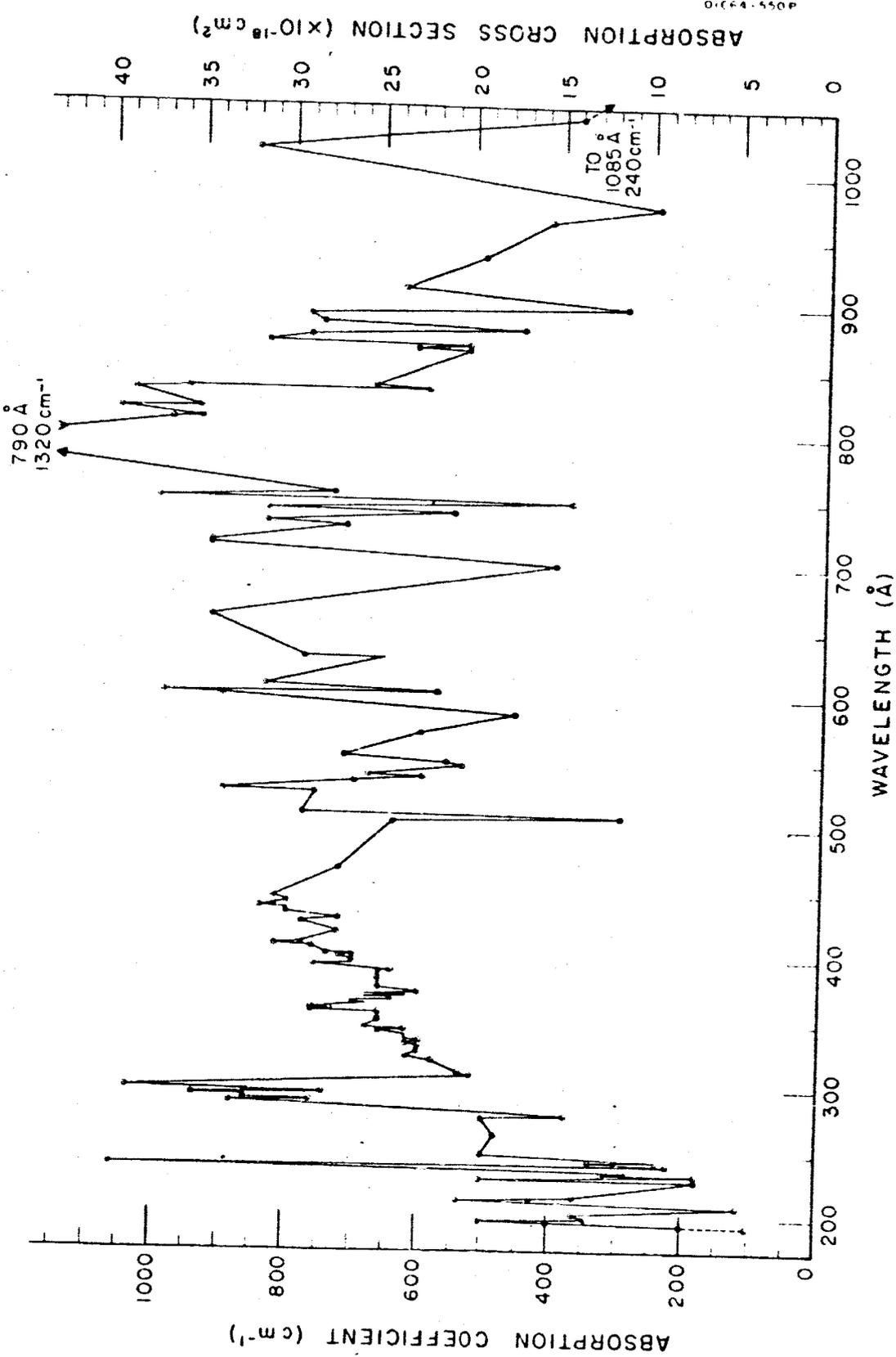
Figure 12



ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF CO
1050 - 1650 \AA

REF.: CURVE, K. WATANABE et al., AFCRC TECH. REP. 53-23, GEOPHYS. RES. PAPER NO. 21 (1953)

Figure 13

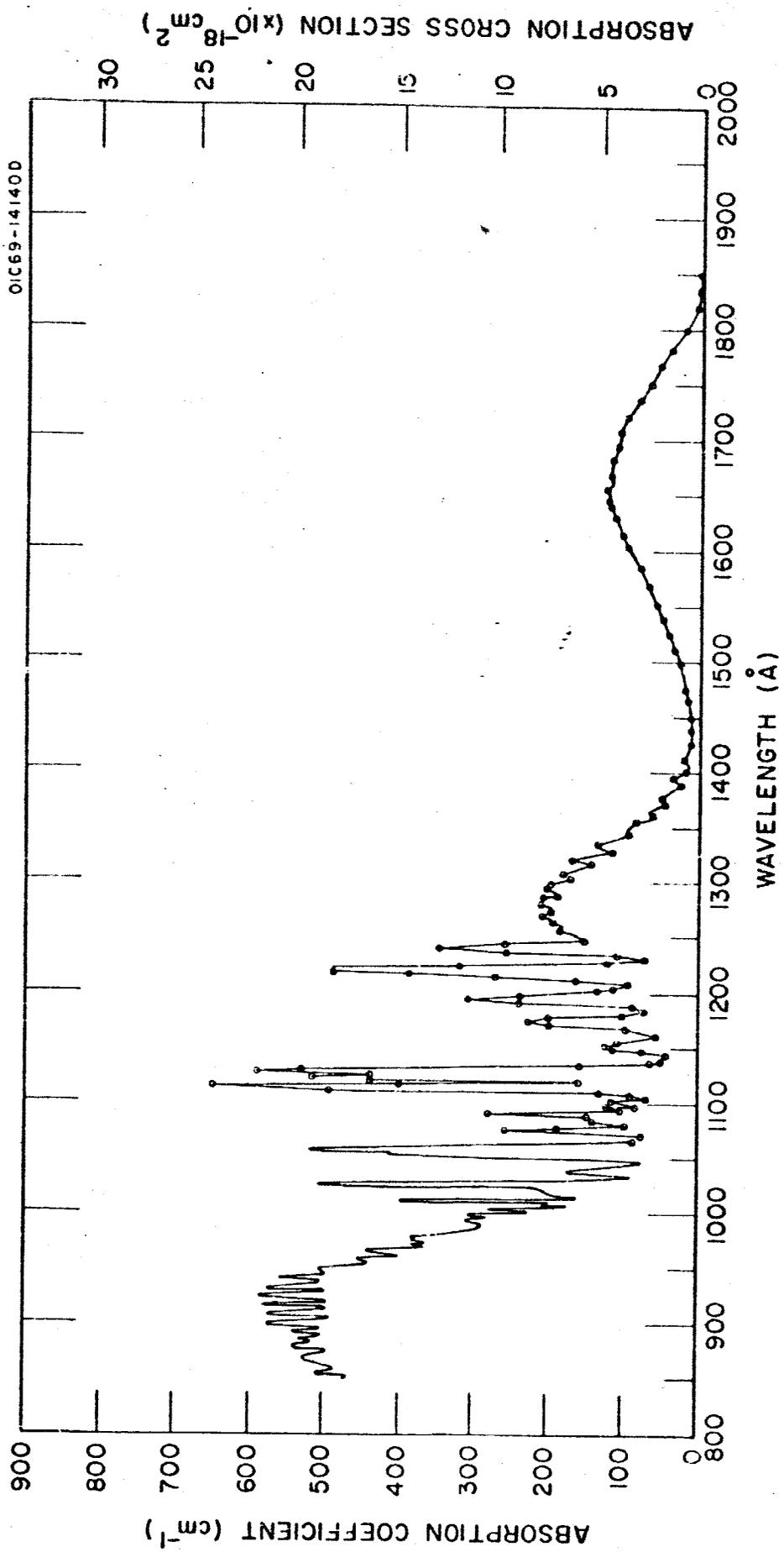


ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF H₂O

REF: J. ROMAND, PRIVATE COMM., JUL 62

ACCURACY: ± 20%; MINIMA ± 10%; MAXIMA ± 50 %

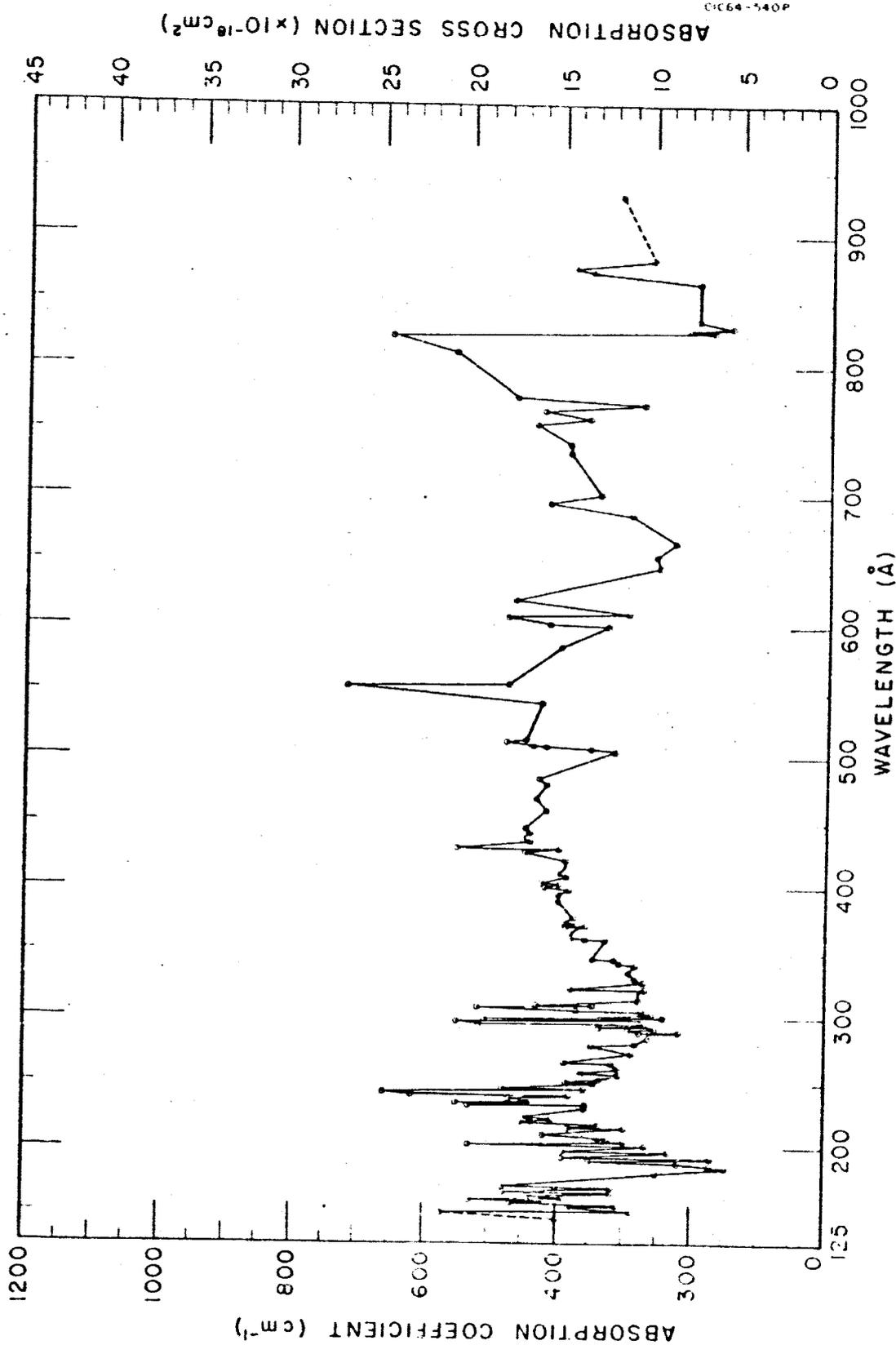
Figure 14



ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF H₂O 850-1850Å

REF.: K. WATANABE et al.,
 850 - 1065Å : ADVANCES IN GEOPHYSICS 5, 199 (1958), CURVE
 1065 - 1850Å : AFCRC TECH. REP. NO. 53-23, GEO. RES. PAPER
 NO. 21, JUNE 1953

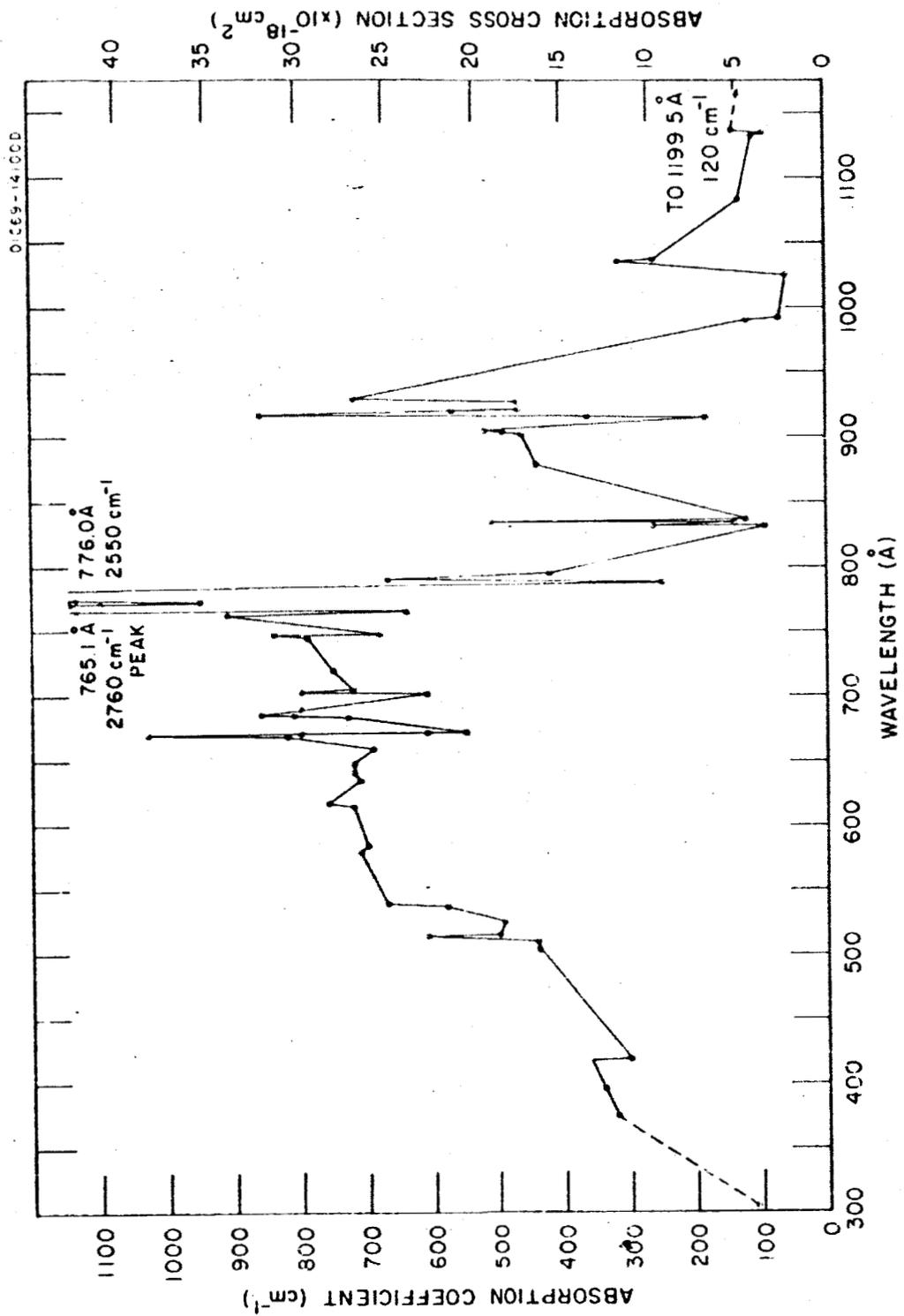
Figure 15



ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF N₂

REF: J. ROMAND, PRIVATE COMM., JUL 62
 ACCURACY: ± 10%; MINIMA ± 10%; MAXIMA ± 50%

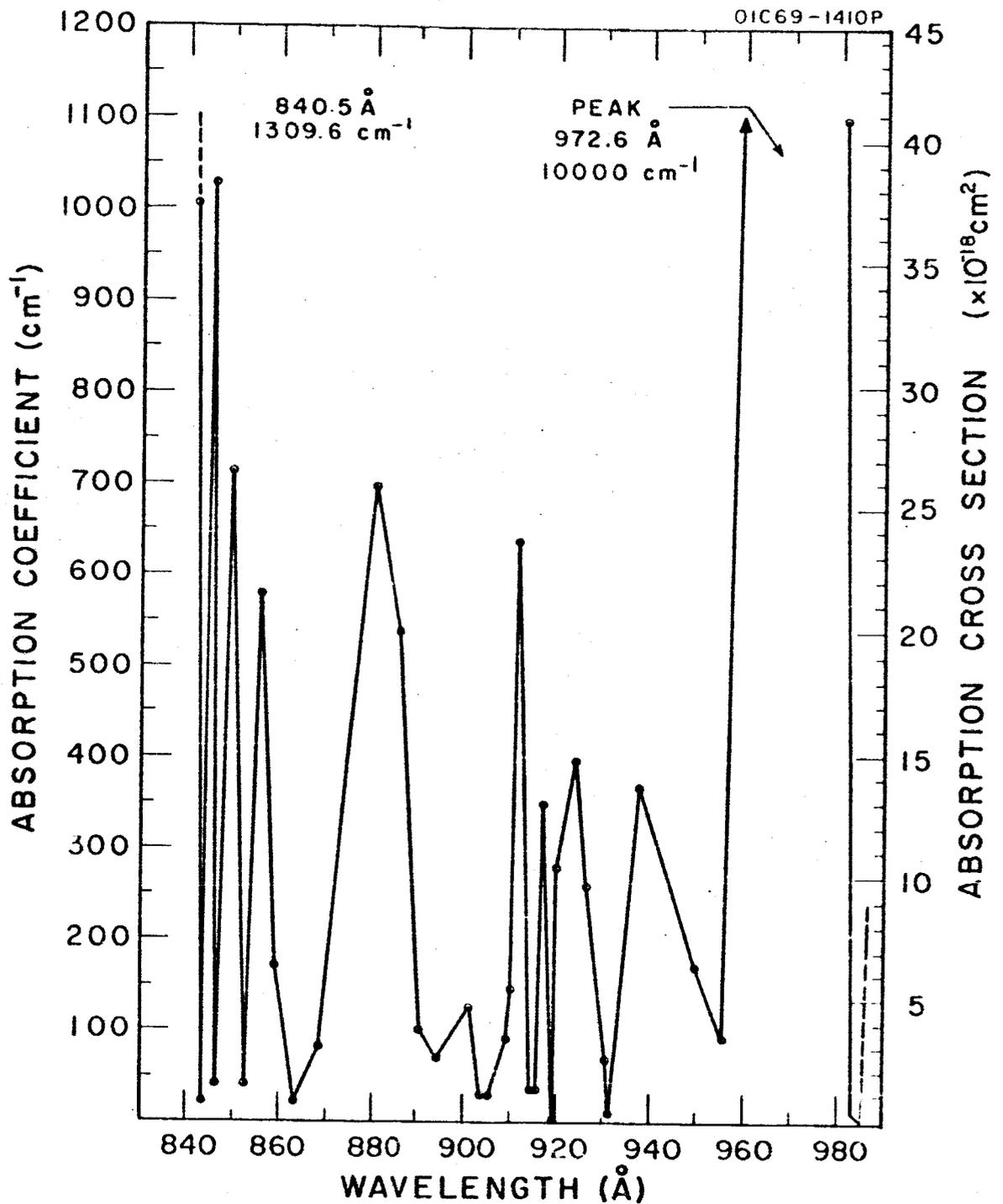
Figure 16



ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF N_2
300-1150 \AA

REF: G.L. WEISSLER, *et al.*, J. OPT. SOC. AM., 42, 84 (1952)
ACCURACY: $\pm 10\%$ K > 100 cm^{-1} , $\pm 15\%$ K \leq 100 cm^{-1}

Figure 17

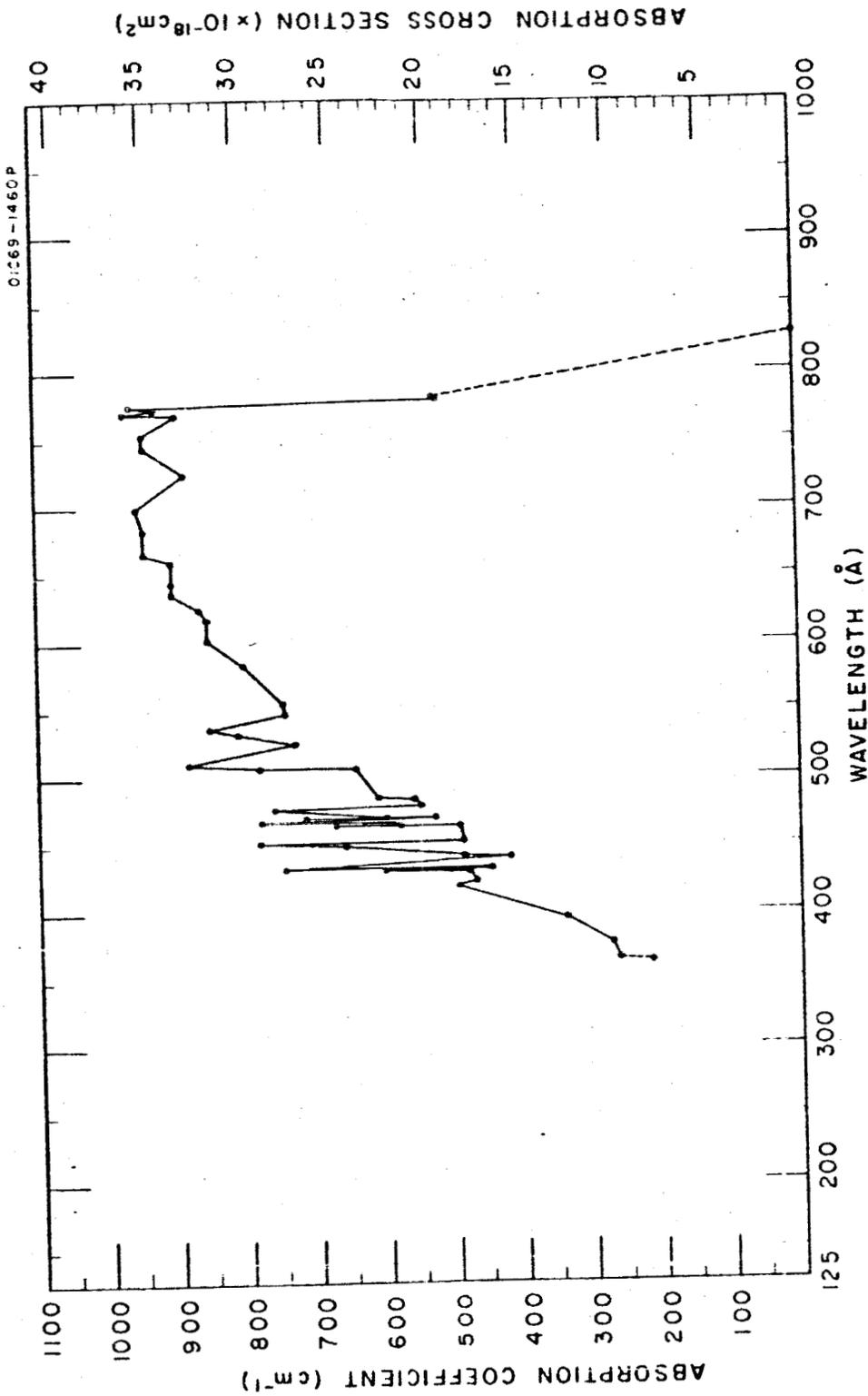


ABSORPTION COEFFICIENTS & CROSS SECTIONS OF N₂ 840-990 Å

REF. : K. WATANABE,
HAWAII INST. OF GEOPHYS. CONTR. NO. 29, DEC. 1961

ACCURACY : ± 15%

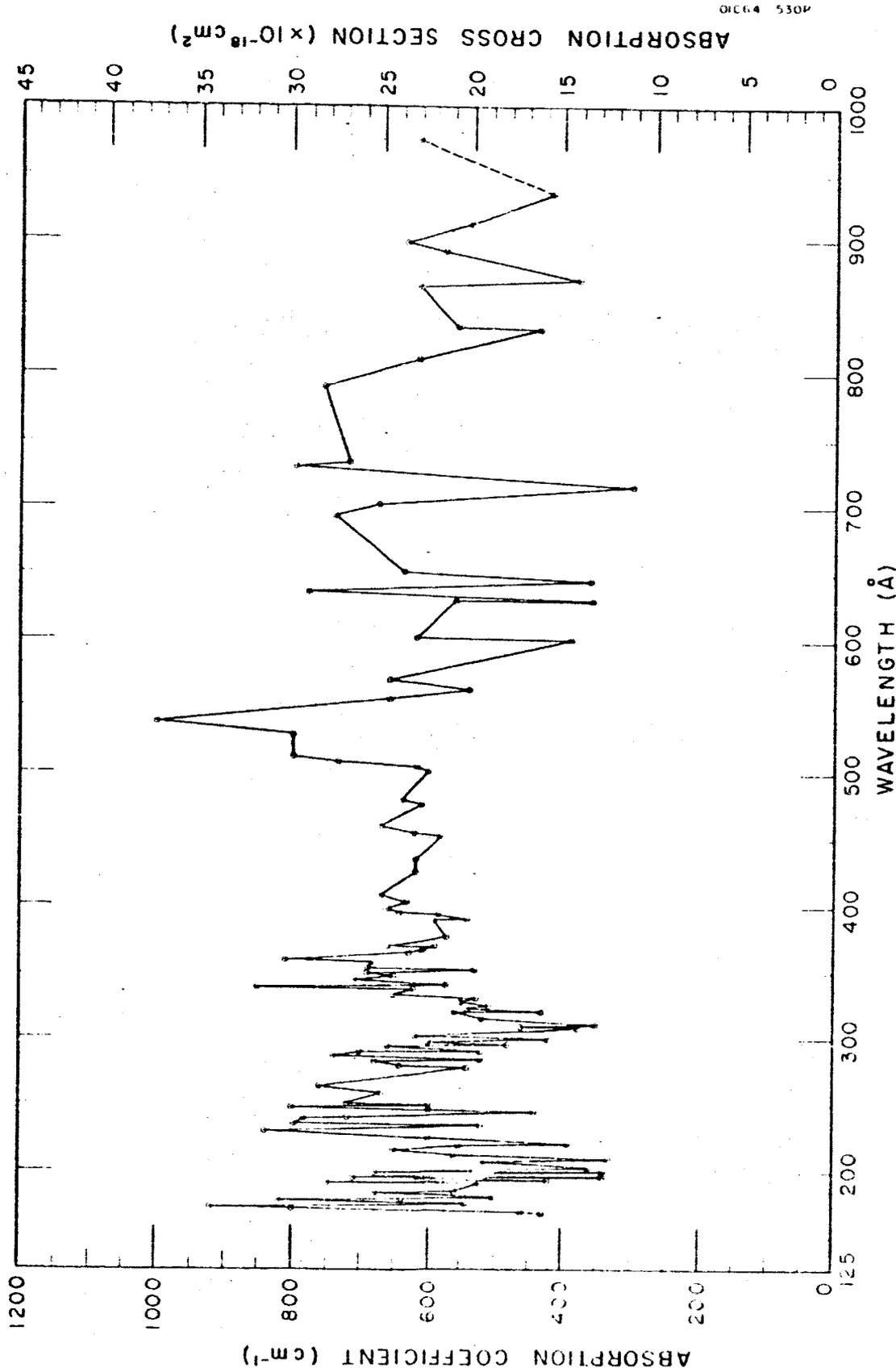
Figure 18



**ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF A
350 - 825 Å**

REF.: P. LEE AND G.L. WEISSLER; PHY. REV. 99 540 (1955); GRAPH BELOW 600 Å
 ACCURACY: 602.8 Å - 827.3 Å: ± 50 CM⁻¹ 363 Å - 584 Å: ± 50 CM⁻¹; ± 1 Å

Figure 19

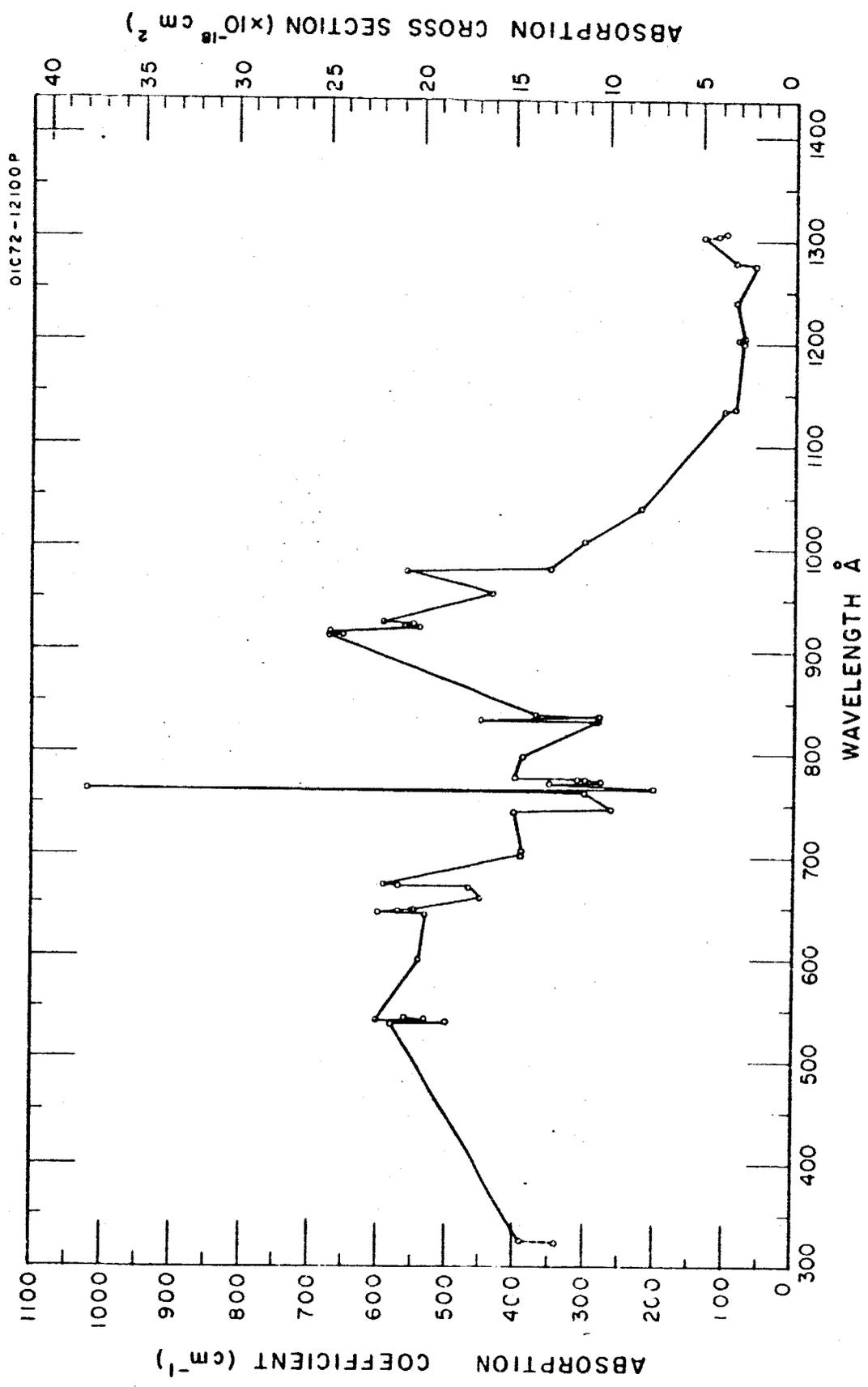


ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF NO

REF: J. ROMAND, PRIVATE COMM., JUL 62

ACCURACY: ± 20%; MINIMA ± 10%; MAXIMA ± 50%

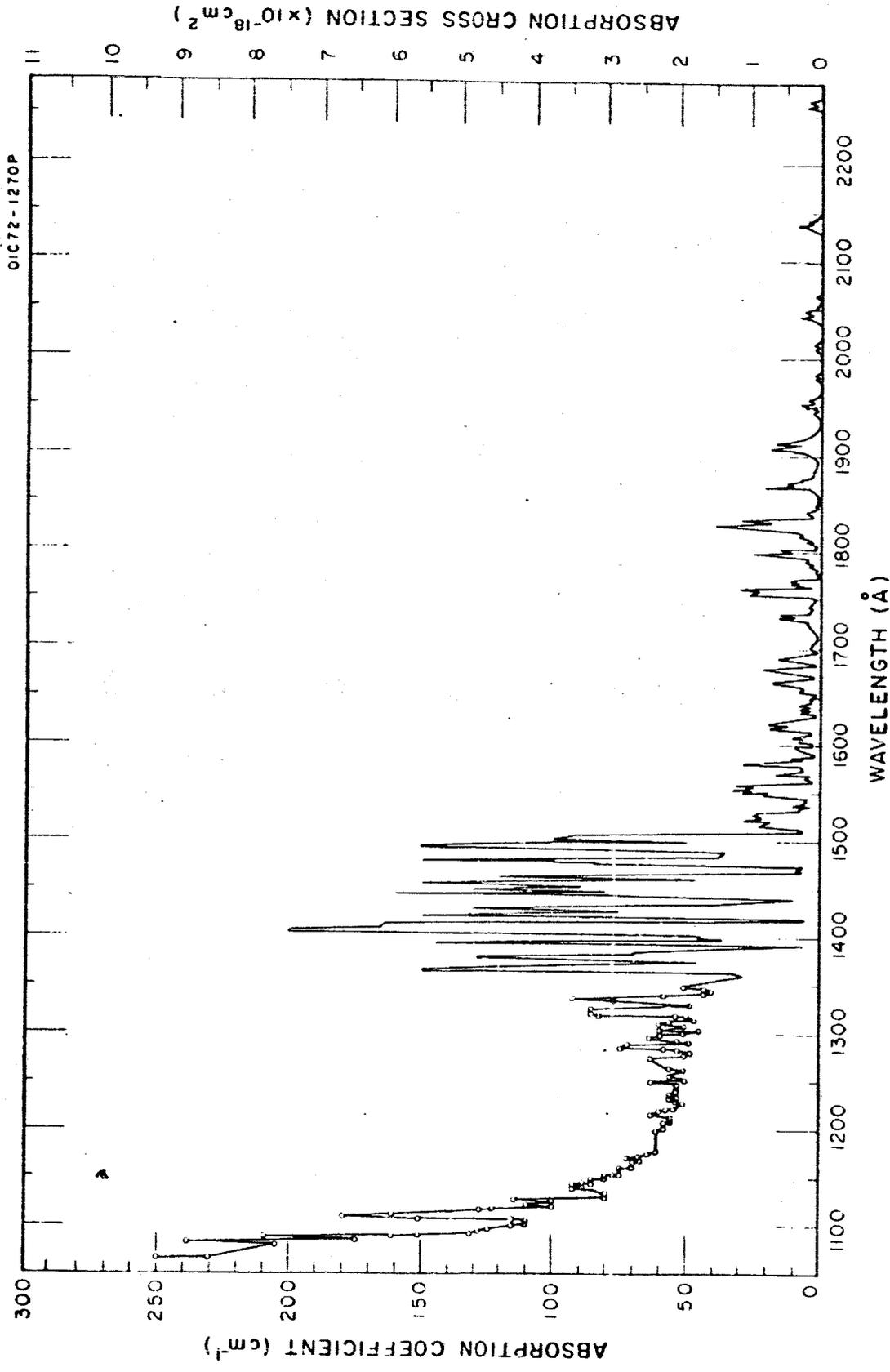
Figure 20



**ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF NO
374Å-1306Å**

REF: H. SUN, G.L. WEISSLER; J. CHEM. PHYS.; 23, 1372 (1955)
ACCURACY: 10 - 15 %

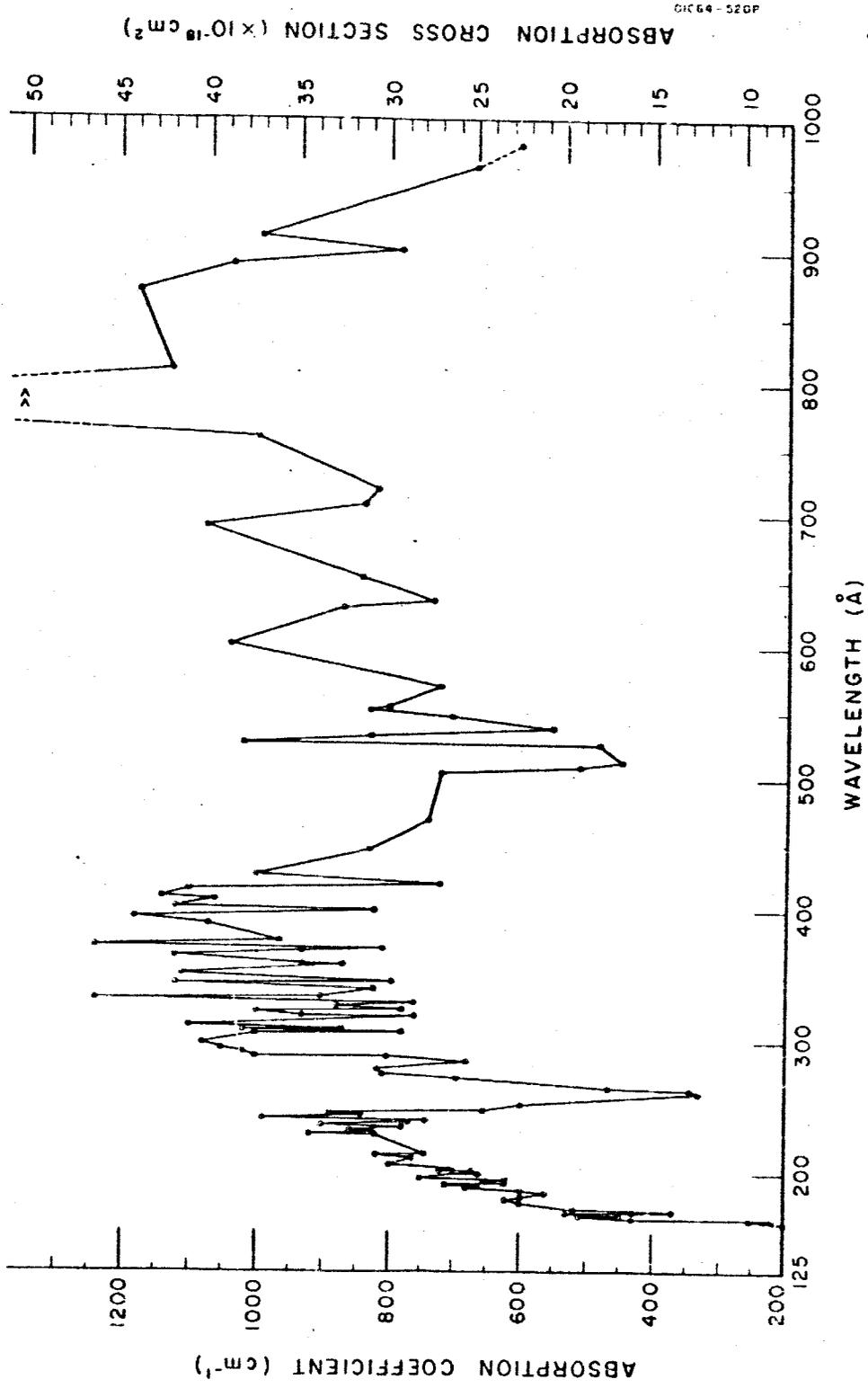
Figure 21



ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF NO
 1065Å - 2300Å

REF: 1065 - 1350 A : K. WATANABE, ADV. IN GEOPHYS., 5, 193 (1958)
 1350 - 2300A : K. WATANABE et al., AFCRC TECH. REPORT NO. 53 - 23,
 GEOPHYS. RES. PAPER NO. 21, JUNE (1953), CURVE

Figure 22

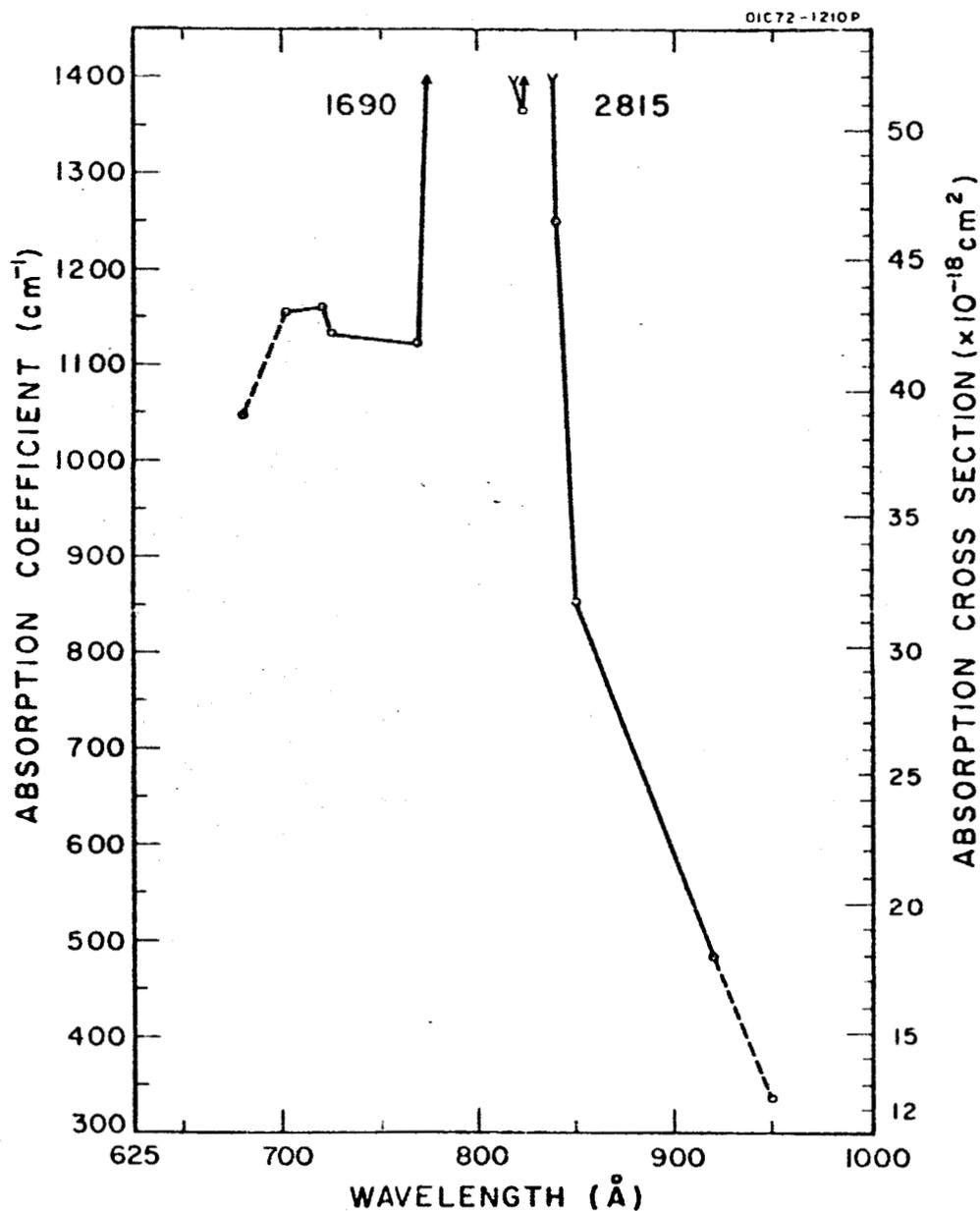


ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF N₂

REF: J. ROMAND, PRIVATE COMM., JUL 62

ACCURACY: ± 20%; MINIMA ± 10%; MAXIMA ± 50%

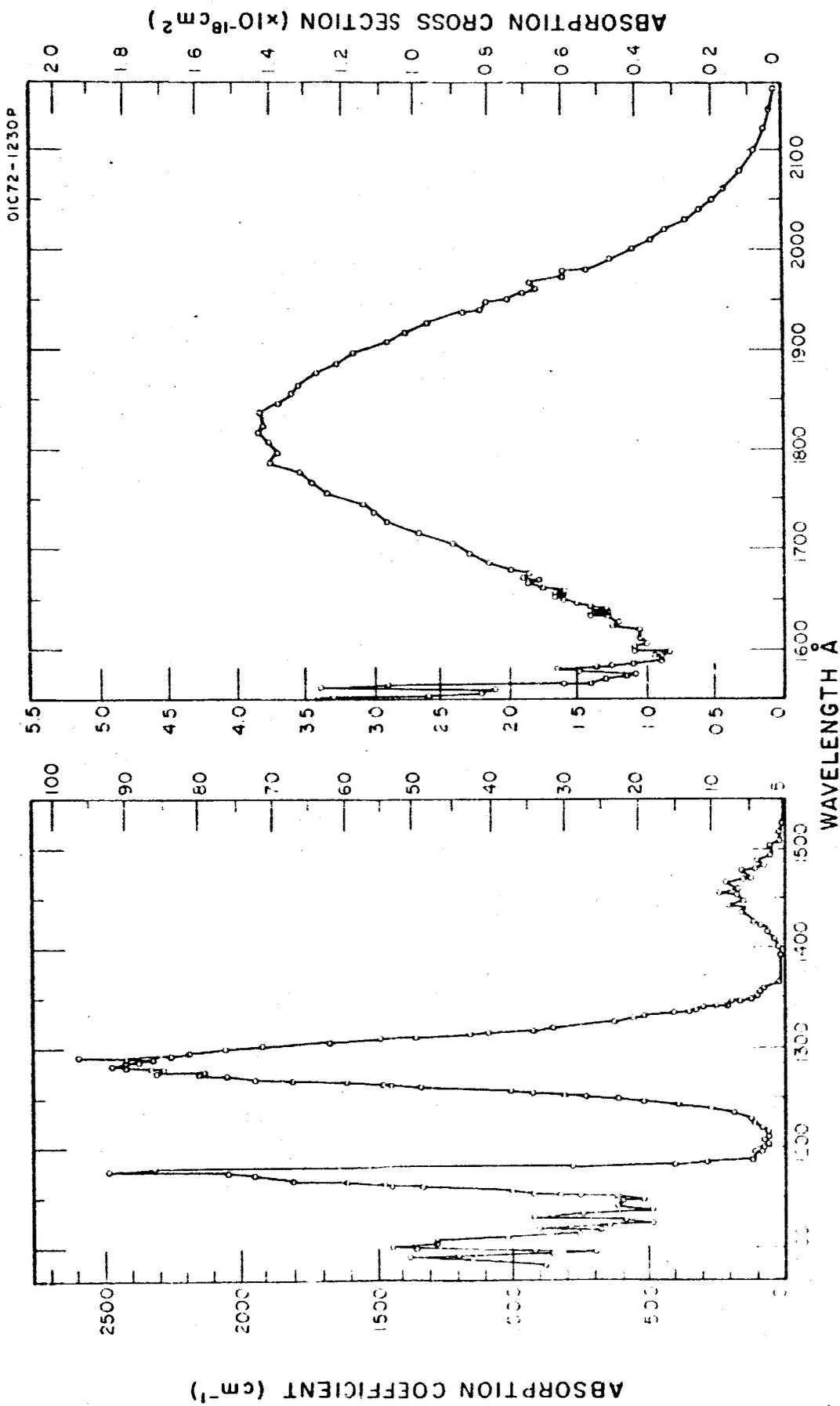
Figure 23



**ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF N₂O
675-950 Å**

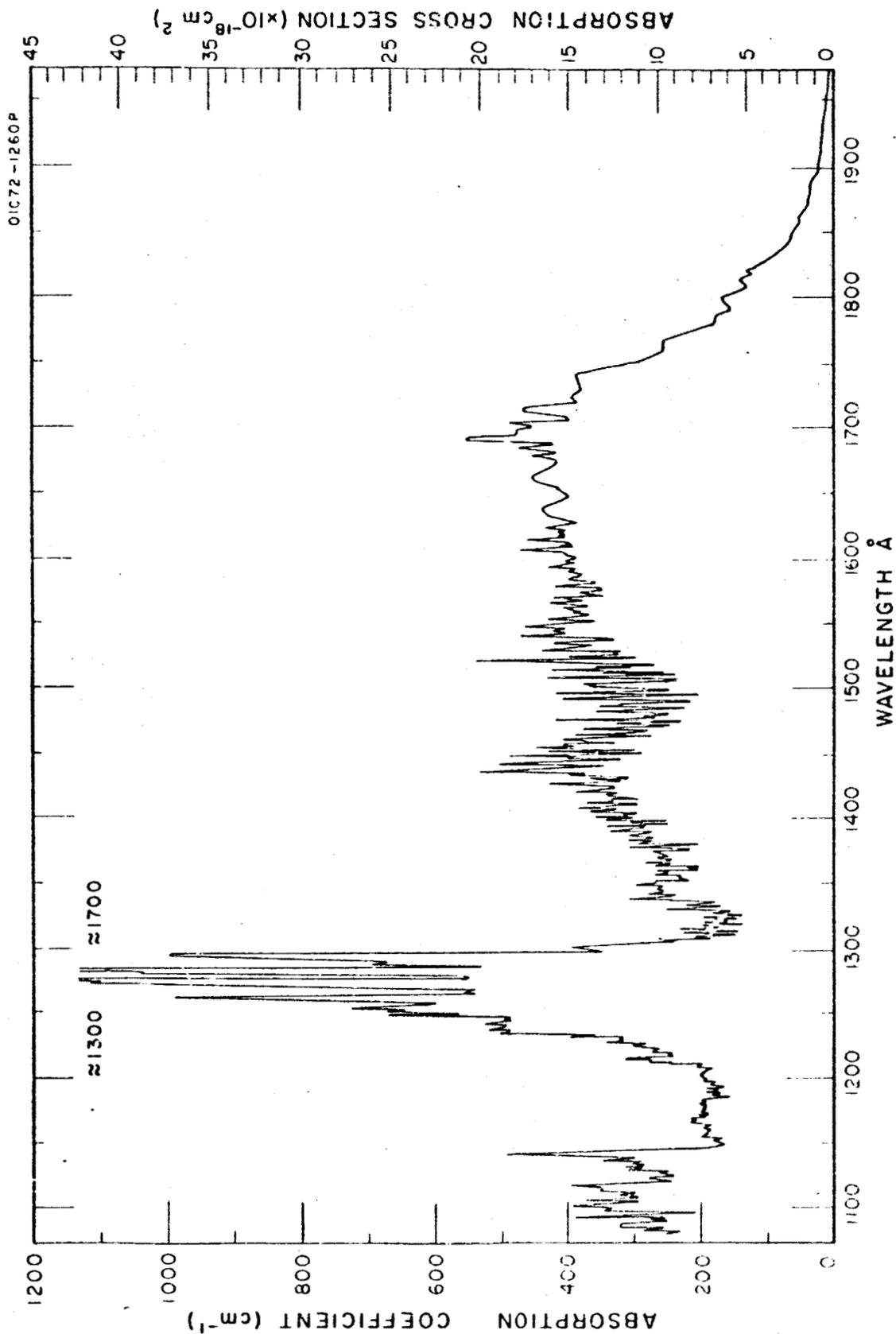
REF: W.C. WALKER, G.L. WEISSLER
J. CHEM. PHYS., 23, 1962 (1955); GRAPH
ACCURACY: ±10%, ±2.5 Å

Figure 24



ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF N₂O 1080Å TO 2160Å

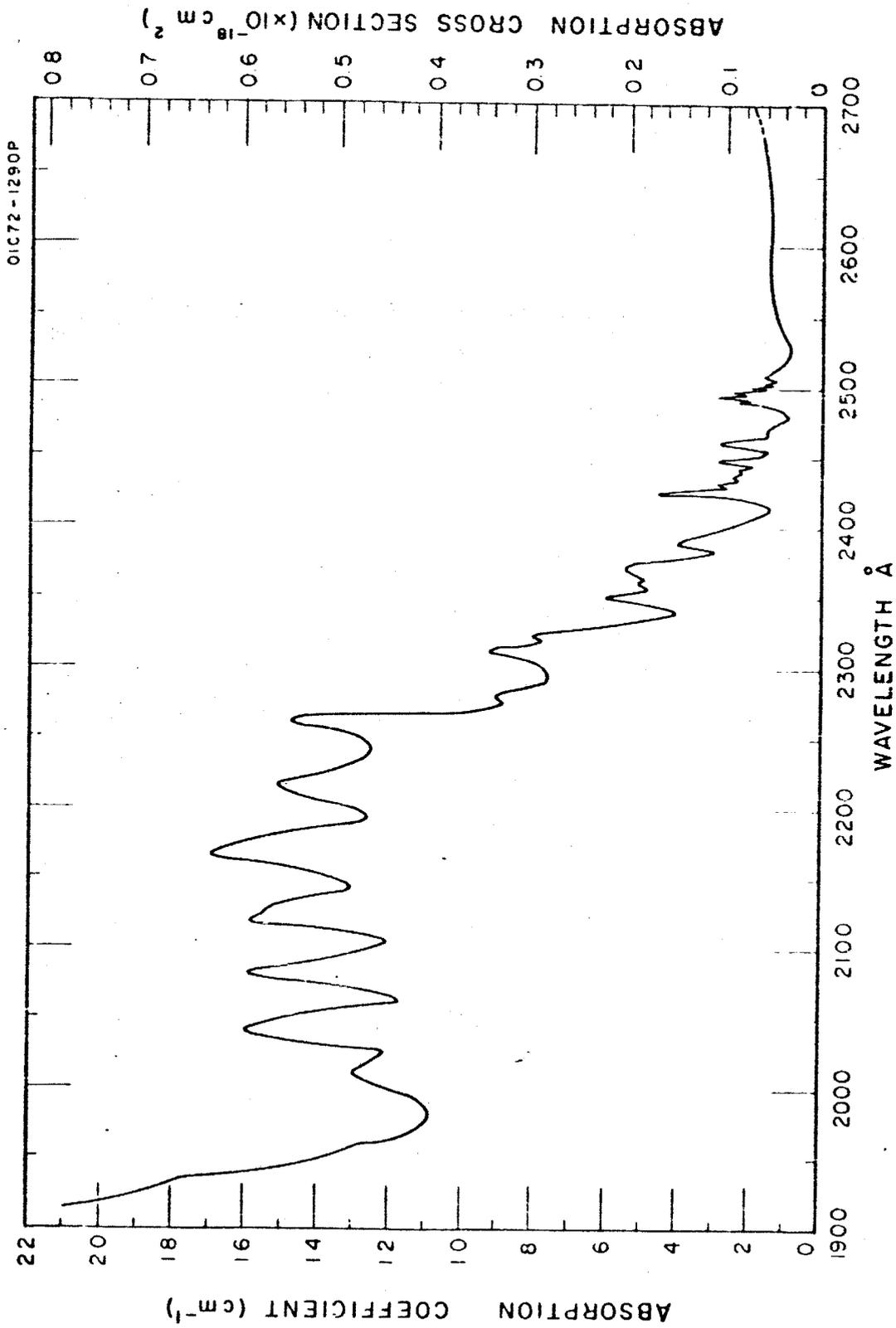
REF: K. WATANABE, et al., AFCRC TECH. REP. NO. 53-23,
GEOPHYS. RES. PAPER NO. 21, JUNE (1953).



ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF NO_2
 1080 \AA TO 1975 \AA

REF: K. WATANABE, et al., HAWAII INST. OF GEOPHYS.
 CONTR. NO. 11 DEC. (1958)
 ACCURACY: 10-20 %

Figure 26



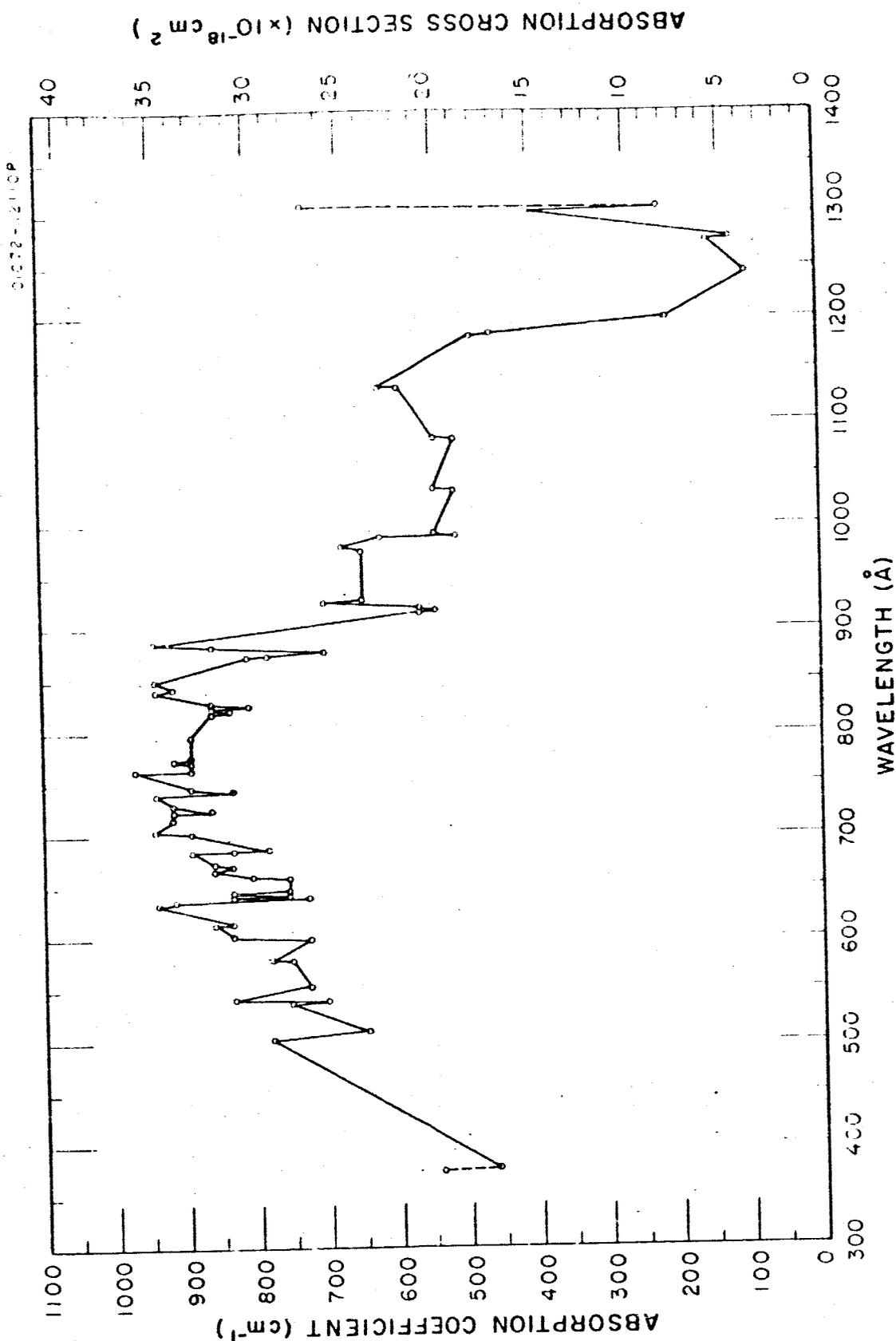
ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF NO_2 1920 \AA TO 2700 \AA

REF: K. WATANABE, et al, HAWAII INST. OF GEOPHYS.

CONTR. NO. 11 DEC. (1958)

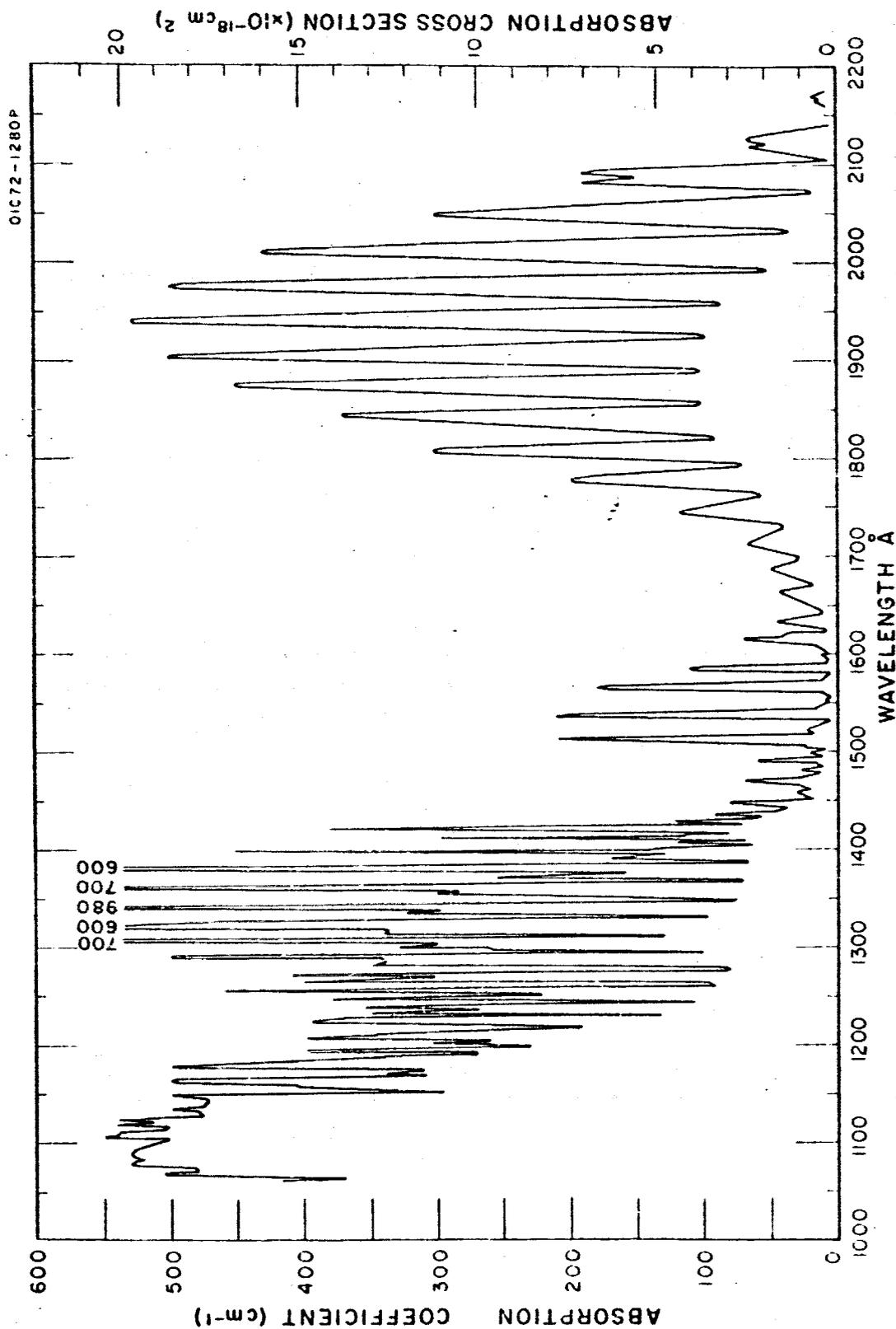
ACCURACY: 30 %

Figure 27



ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF NH₃
374Å - 1306Å

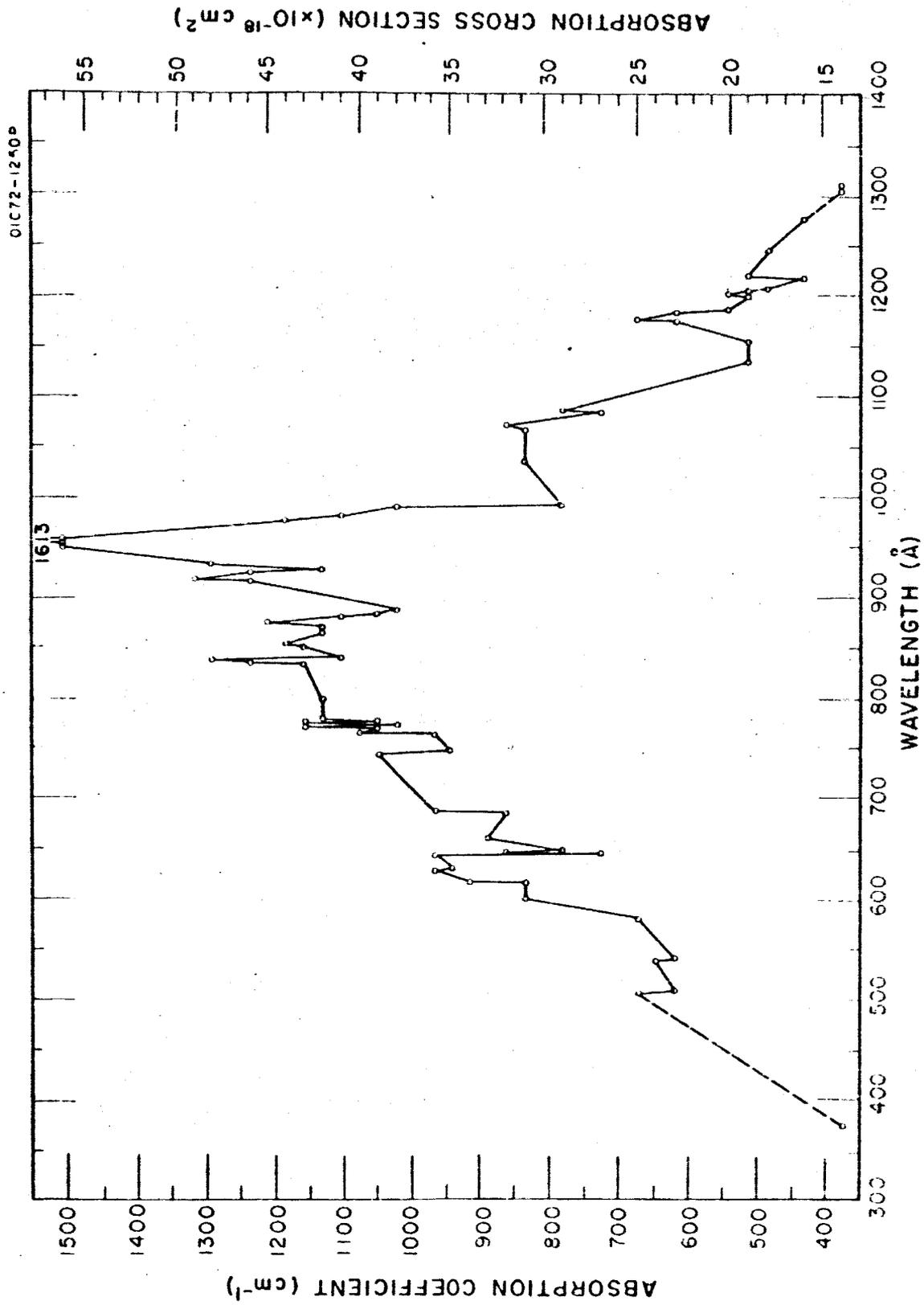
REF: H. SUN, G.L. WEISSLER, J. CHEM. PHYS.; 23, 1160 (1955)
 ACCURACY: AVE. 10%



ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF NH₃ 1060 Å TO 2200 Å

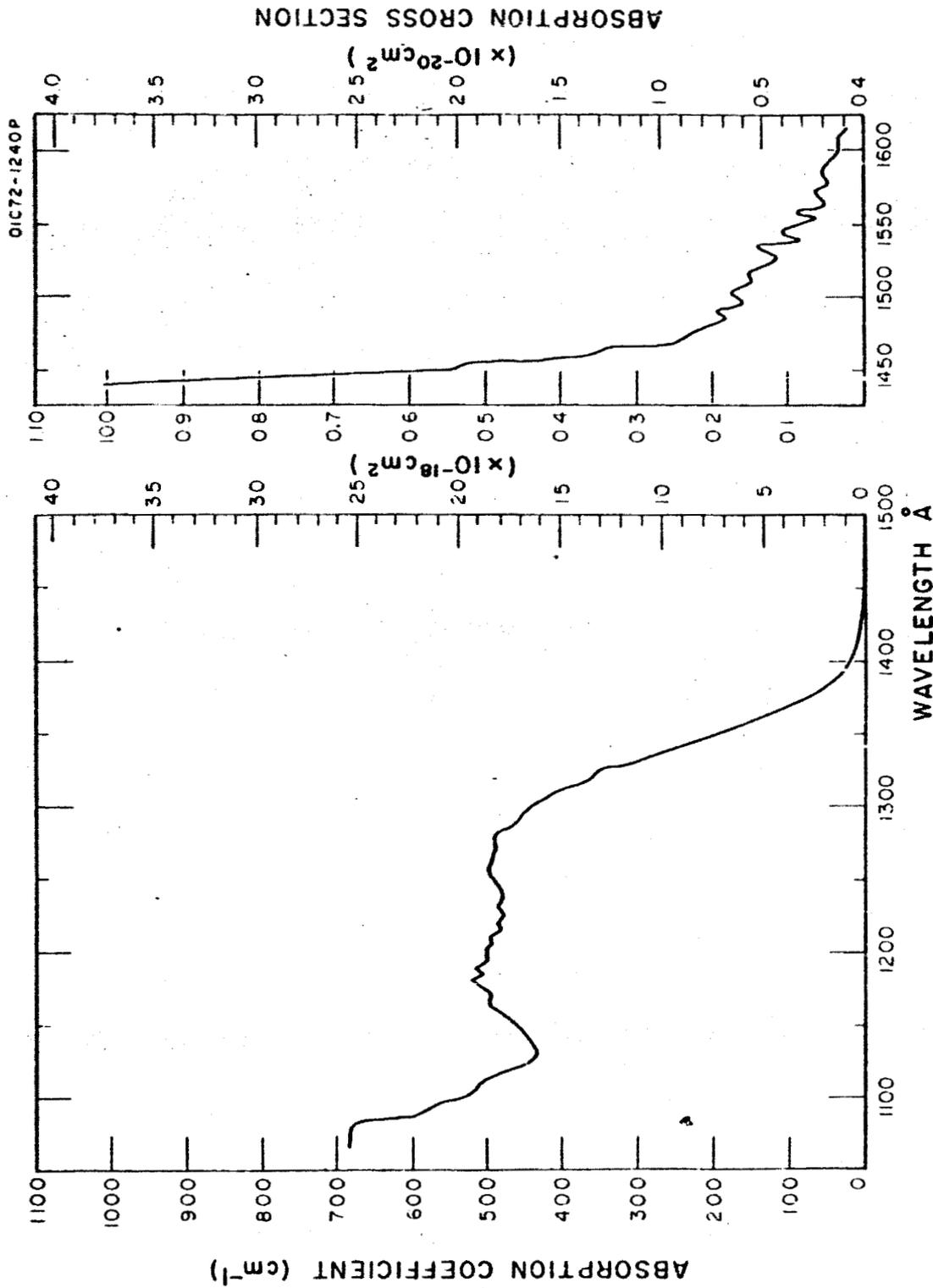
REF: K. WATANABE, et al., AFCRC TECH. REP. NO. 53-23,
GEO. RES. PAPER NO. 21, DEC. (1953), CURVE.
PEAK VALUES ARE APPROXIMATE

Figure 29



ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF CH₄
374 Å - 1306 Å

REF: H. SUN, G.L. WEISSLER; J. CHEM. PHYS.; 23, 1160 (1955)
 ACCURACY: AVE. 10 %



ABSORPTION COEFFICIENTS AND CROSS SECTIONS OF CH₄
 1065Å - 1610Å

REF: K. WATANABE, et al., AFCRC TECH. REP. NO. 53-23,
 GEOPHYS. RES. PAPER NO. 21, DEC. (1953), CURVE

Figure 31

DIRECT REFERENCES

1. Aboud, A.A., Curtis, J.P., Mercure, R., and Rense, W.A.,
J. Opt. Soc. Am. 53, 767 (1955).
2. Ditchburn, R.W., and Young, P.A., J. Atmos. & Terres. Phys. 24,
127 (1962).
3. Goldberg, L., "The Earth as a Planet" (Kuiper, G.P. ed.)
U. of Chicago Press pp. 434-490 (1954).
4. Hearn, A.G., Proc. Phys. Soc. 78, 932 (1961).
5. Inn, E.C.Y., and Tanaka, Y., J. Opt. Soc. Am. 43, 870 (1953).
6. Inn, E.C.Y., and Tanaka, Y., Adv. in Chem. Series No. 21.
Am. Chem. Soc. pp. 263-268 (1959).
7. Inn, E.C.Y., Watanabe, K., and Zelikoff, M., J. Chem. Phys. 21,
1648 (1953).
8. Lee, P., J. Opt. Soc. Am. 45, 703 (1955).
9. Lee, P., and Weissler, G.L., Phys. Rev. 99, 540 (1955).
10. Matsunaga, F.M., and Watanabe, K., Hawaii Inst. Geophys. Contr.
No. 33, (1961).
11. Ogawa, M., and Cook, G.R., J. Chem. Phys. 28, 173 (1958).
12. Romand, J., Private Communication (1962).
13. Sun, H., and Weissler, G.L., J. Chem. Phys. 23, 1160 (1955a),
1372 (1955b), 1625 (1955c).
14. Tanaka, Y., J. Chem. Phys. 20, 1728 (1952).
15. Tanaka, Y., J. Opt. Soc. Am. 45, 663 (1955).
16. Tanaka, Y., Inn, E.C.Y., and Watanabe, K., J. Chem. Phys. 21,
1651 (1953).
17. Wainfan, N., Walker, W.C., and Weissler, G.L., Phys. Rev. 99,
542 (1955).
18. Walker, W.C., and Weissler, G.L., J. Chem. Phys. 23, 1962 (1955).

DIRECT REFERENCES (Continued)

19. Watanabe, K., "Adv. in Geophys." (Landsberg, H.E., and Van Mieghen, J. eds.) 5, Academic Press, New York, pp. 153-221, (1958).
20. Watanabe, K., Hawaii Inst. Geophys, Contr. No. 29, (1961).
21. Watanabe, K., and Marmo, F.F., J. Chem. Phys. 25, 965, (1956).
22. Watanabe, K., and Zelikoff, M., J. Opt. Soc. Am. 43, 753 (1953).
23. Watanabe, K., Inn, E.C.Y., and Zelikoff, M., J. Chem. Phys. 20, 1969 (1952).
24. Watanabe, K., Inn, E.C.Y., and Zelikoff, M., J. Chem. Phys. 21, 1026 (1953a).
25. Watanabe, K., Zelikoff, M., and Inn, E.C.Y., AFCRC Tech. Rep. No. 53-23 Geophys. Res. Paper No. 21 (1953b).
26. Watanabe, K., Sakai, H., Mottl, J., and Nakayama, T., Hawaii Inst. Geophys. Contr. No. 11 (1958).
27. Weissler, G.L., "Encyclopedia of Physics" (S. Flügge ed.) XXI, Springer-Verlag, Berlin, pp. 304-382, (1959).
28. Weissler, G.L., and Lee, P., J. Opt. Soc. Am. 42, 200 (1952).
29. Weissler, G.L., Lee, P., and Mohr, E.I., J. Opt. Soc. Am. 42, 84 (1952).
30. Weissler, G.L., Sampson, J.A.R., Ogawa, M., and Cook, G.R., J. Opt. Soc. Am. 49, 338 (1959).
31. Zelikoff, M., Watanabe, K., and Inn, E.C.Y., J. Chem. Phys. 21, 1643 (1953).

INDIRECT REFERENCES

- Adel, A. *Astrophys. J.* 90, 627 (1939).
- Astoin, N., *C.R. Acad. Sci. Paris* 242, 2327 (1956).
- Astoin, N., and Granier, J., *Compt. Rend.* 244, 1350 (1957).
- Astoin, N., Johannin, A., and Vodar, B., *C.R. Acad. Sci. Paris* 237, 558 (1953).
- Birge, R.T., and Hopfield, J.J., *Ap. J.* 68, 257 (1928).
- Brix, P., and Herzberg, G., *Canad. J. Phys.* 32, 110 (1954).
- Broida, H.P., and Gaydon, A.G., *Canad. J. Phys.* 32, 110 (1954).
- Chalonge, D., and Vassy, E., *C.R. Acad. Sci. Paris* 198, 1318 (1934).
- Clark, K.C., *Phys. Rev.* 87, 21, 271 (1952).
- Curry, J., and Herzberg, G., *Ann. d. Phys.* 19, 800 (1934).
- Curtis, J.P., *Phys. Rev.* 94, 908 (1954).
- Ditchburn, R.W., *Proc. Roy. Soc. (London)* A229, 44 (1955).
- Ditchburn, R.W., and Heddle, D.W.O., *Proc. Roy. Soc. (London)* A220, 61 (1953).
- Ditchburn, R.W., Bradley, J.E.S., Cannon, C.G., and Munday, G., "Rocket Expl. of Upper Atmos." (R.L.E. Boyd and M.J. Seaton, eds.) pp. 327-334 (1954).
- Dixon, J.K., *Phys. Rev.* 43, 711 (1933).
- Duncan, A.B.F., *Phys. Rev.* 47, 822 (1935).
- Duncan, A.B.F., *J. Chem. Phys.* 4, 633 (1936a).
- Duncan, A.B.F., *Phys. Rev.* 50, 700 (1936b).
- Duncan, A.B.F., and Howe, J.P., *J. Chem. Phys.* 2, 851 (1934).
- Fabry, C., and Buisson, H., *J. de Phys.* 3, 196 (1913).
- Fabry, C., and Buisson, H., *Ap. J.* 54, 297 (1921).

INDIRECT REFERENCES (Continued)

- Fowler, A., and Strutt, R.J. (Lord Rayleigh), Proc. Roy. Soc. (London) A93, 577 (1917).
- Granier, J., and Astain, N., Compt. Rend. 242, 1431 (1956).
- Hagstrum, H.D., Rev. Mod. Phys. 23, 185 (1951).
- Harrison, A.J., Cederholm, B.J., and Coffin, E.M., Tech. Rpt., Mt. Holyoke College, Holyoke, Mass., pp. 21-24 (1951).
- Hartley, W.N., J. Chem. Soc. 39, 57, 111 (1881).
- Heilpern, W., Helv. Phys. Acta, 14, 329 (1941).
- Henning, H.J., Ann. Physik 13, 599 (1932).
- Herzberg, G., Naturwissenschaften 20, 577 (1932).
- Herzberg, G., Canad. J. Phys. 30, 185 (1952).
- Hopfield, J.J., Phys. Rev. 36, 789 (1930).
- Hopfield, J.J., Astrophys. J. 72, 133 (1930).
- Hopfield, J.J., Astrophys. J. 104, 208 (1946).
- Hopfield, J.J., and Birge, R.T., Phys. Rev. 29, 922 (1927).
- Huggins, W., Proc. Roy. Soc. (London) 48, 216 (1890).
- Johannin-Giles, A., C.R. Acad. Sci. Paris 236, 676 (1953).
- Knauss, H.P., and Ballard, S.S., Phys. Rev. 48, 796 (1935).
- Ladenburg, R., and VanVoorhis, C.C., Phys. Rev. 43, 315 (1933).
- Leifson, S.W., Astrophys. J. 63, 73 (1926).
- Lyman, T., Astrophys. J. 27, 87 (1908).
- Lyman, T., Astrophys. J. 57, 161 (1911).
- Marmo, F.F., J. Opt. Soc. Am. 43, 1186 (1953).
- Marmo, F.F., Thesis, Dept. of Chemistry, Harvard University, Cambridge, Massachusetts (1954).

INDIRECT REFERENCES (Continued)

- Mayence, J., *Ann. Phys.* 7, 453 (1952).
- Meinel, A.B., *Rep. Progr. Phys.* 14, 121 (1951).
- Moe, G., and Duncan, A.B.F., *J. Am. Chem. Soc.* 74, 3140 (1952).
- Mori, K., *Science of Light (Tokyo)* 3, 62 (1954).
- Mori, K., *Science of Light (Tokyo)* 4, 130 (1955).
- Ny, T.-Z., and Choong, S.-P., *Chin. J. Phys.* 1, 38 (1933).
- Ny, T.-Z., and Choong, S.-P., *Compt. Rend.* 195, 309 (1932).
- Ny, T.-Z., and Choong, S.-P., *Compt. Rend.* 196, 916 (1933).
- Pillow, M.E., *Proc. Phys. Soc. (London)* A66, 733 (1953).
- Preston, W.M., *Phys. Rev.* 57, 887 (1940).
- Price, W.C., *J. Chem. Phys.* 4, 147 (1936).
- Price, W.C., and Collins, G., *Phys. Rev.* 48, 714 (1935).
- Price, W.C., and Simpson, D.M., *Proc. Roy. Soc. (London)* A169, 501 (1938).
- Price, W.C., and Simpson, D.M., *Trans. Faraday Soc.* 37, 106 (1941).
- Rathenau, G., *Z. Physik* 87, 32 (1933).
- Rose, A., *Z. Physik* 81, 745 (1933).
- Schneider, E.G., *J. Chem. Phys.* 5, 106 (1937).
- Sen-Gupta, P.K., *Nature* 136, 513 (1935).
- Stopes-Roe, H., *M. Sci. Thesis (unpublished London Univ.)* (1947).
- Stueckelberg, E.C.G., *Phys. Rev.* 42, 518 (1932).
- Tanaka, Y., Jursa, A.S., and LeBlanc, F.J., *Abst. Symposium Molec. Structure and Spectroscopy*, p. 50. Columbus, Ohio (1957).
- Tanaka, Y., and Takamine, T., *Sci. Pap. Inst. Phys. Chem. Res. Tokyo* 39, 427, 437, 447 (1942).

INDIRECT REFERENCES (Continued)

- Tanaka, Y., and Takamine, T., Sci. Pap. Inst. Phys. Chem. Res. Tokyo 40, 371 (1943).
- Tannenbaum, E., Coffin, E.M., and Harrison, A.J., J. Chem. Phys. 21, 311 (1953).
- Vigroux, E., Ann. Phys. Paris 8, 709 (1953).
- Vigroux, E., Bull. Soc. Chem. Fr. 402 (1949).
- Vigroux, E., C.R. 234, 2351, 2439, 2529, 2592 (1952).
- Watanabe, K., and Jursa, A., unpublished material. See Direct Ref. No. 19, p. 199.
- Wilkinson, P.G., and Johnston, H.L., J. Chem. Phys. 18, 190 (1950).
- Wilkinson, P.G., and Mulliken, R.S., Astrophys. J. 125, 594 (1957).
- Worley, R.E., Phys. Rev. 64, 207 (1943).
- Worley, R.E., and Jenkins, F.A., Phys. Rev. 54, 305 (1938).